5.0 NUMERICAL MODELING OF GENERAL AND WARD CREEKS AND THE UPPER TRUCKEE RIVER

5.1 Introduction

Numerical simulations of upland and channel processes using AnnAGNPS and CONCEPTS, respectively were carried out on three representative watersheds to:

(1) Determine the relative contributions of sediment from upland and channel sources;
(2) Simulate the effects of the January 1997 runoff event on future sediment loads;
(3) Evaluate 50-year trends in suspended-sediment delivery to Lake Tahoe from the three watersheds.

5.2 Input Database for the AGNPS Model

The development of input parameters used for AnnAGNPS to describe the Lake Tahoe watersheds conditions involved assembling many sources of available information, such as elevation maps, soil data, landuse and operation management data, and especially weather information. All of the required model parameters can be selected from the available data, which is available publicly or obtained from the measured data collection phase needed for CONCEPTS. The compilation of the data into the form needed by AnnAGNPS was performed using the AGNPS Arcview Interface and the AnnAGNPS Input Editor.

5.2.1 GIS Database

The use of a geographic information system (GIS) is critical in gathering the needed data to perform simulations for watersheds of the size contained in the Lake Tahoe basin. The GIS data provides the vital link between the characteristics of the watershed and the parameters needed by the model. Fortunately, for the Lake Tahoe basin there is a data warehouse that serves as a central location for much of the GIS data available for any watershed in the basin. The Lake Tahoe Data Clearinghouse Internet web site is produced by the United States Geological Survey (USGS) and is located at http://tahoe.usgs.gov/.

For the application of the entire suite of AGNPS, the basic GIS data needed are: the digital elevation models (DEMs) to describe the topography; the landuse GIS layer to describe the vegetative cover; and, a soils GIS layer, which all together can provide the spatial variation of the important characteristics of the watershed. Additional GIS data is useful in assessing the creation of model parameters and the impact various features may have on the watershed system. This can include digitized quad sheets, aerial photographs, location of streams, roads, erosion control structures on fields and in the channels, lakes, and other features impacting the watershed. For information that is not available from digital sources, information may be digitized from other maps, or transferred from field work using global positioning system (GPS) techniques.

The projection used for the AGNPS data development by all of the GIS data layers was the UTM NAD27 zone 10 projection. This provided consistency among all of the layers when data was analyzed or paper maps were produced. Other GIS layers can easily be reprojected from another projection to the UTM projection.

Topographic Analysis

Every watershed has unique topography that is difficult to characterize without having maps that describe the elevation throughout the watershed. Topographic information is crucial in determining the watershed and subwatershed boundaries, channel locations, channel slopes, routing of flow from fields to channels to the watershed outlet, field slopes, travel time of flows, the RUSLE LS-factor, aspect and elevation of fields. The use of DEMs provides a convenient source of topographic information, but often is derived from basic topographic contours, such as USGS 7.5 minute quad maps. Thus, the resolution can range from 120m x 120m raster grids with 5m elevations, to 30m x 30m with 1m elevations, to 10m x 10m with 0.1m elevations, depending on the source of the DEMs. The 10m x 10m raster grid can provide a better definition of the watershed topography, but generates a much larger file size needed to store the data. Other considerations in using the 10m x 10m raster grid are that this will require more computer resources to execute the AGNPS topographic tools, such as more memory, more hard disk space, and additional computational time. Also, the 10m x 10m DEM raster grid is available from MARIS with the elevation provided in feet and requires the conversion to meters before using TOPAGNPS, while the 30m x 30m DEM already has the elevation in meters. The current modeling effort used 10m x 10m raster grid.

Digital Elevation Model (DEM)

The USGS Western Geographic Science Center created DEMs with 10m x 10m resolution from 18 7.5-minute quadrangle hypsographic maps that have 40 ft contours covering the entire Lake Tahoe Basin (Figure 5-1). From this DEM, each of the DEMs covering the watersheds of General Creek, Ward Creek, and Upper Truckee River were clipped and used individually for to develop AnnAGNPS data sets to minimize the computational time needed for the topographic analysis of each watershed. The Upper Truckee River watershed DEM was clipped closely to the expected boundary to minimize the amount of the Trout Creek watershed that would be captured during the topographic analysis procedure. The confluence of Trout Creek and the Upper Truckee River occurs near Lake Tahoe and only the Upper Truckee River watershed was simulated.

Modification of Digital Elevation Models (DEMs)

The modification of DEMs may be required when local features within a watershed are not captured during the development of the DEM. This could be because of recent human activities that change the elevation within areas of the watershed. This includes land-leveling of fields, channel straightening, road construction, or development of ditches to route water around fields or residential areas. The watershed characteristics generated by AGNPS components then may not correspond to actual stream locations or watershed boundaries. To account for these topographic variances, the DEM is modified to adopt the required features. More likely areas that may require modification of a DEM are measures that have produced straightened or altrered channels.

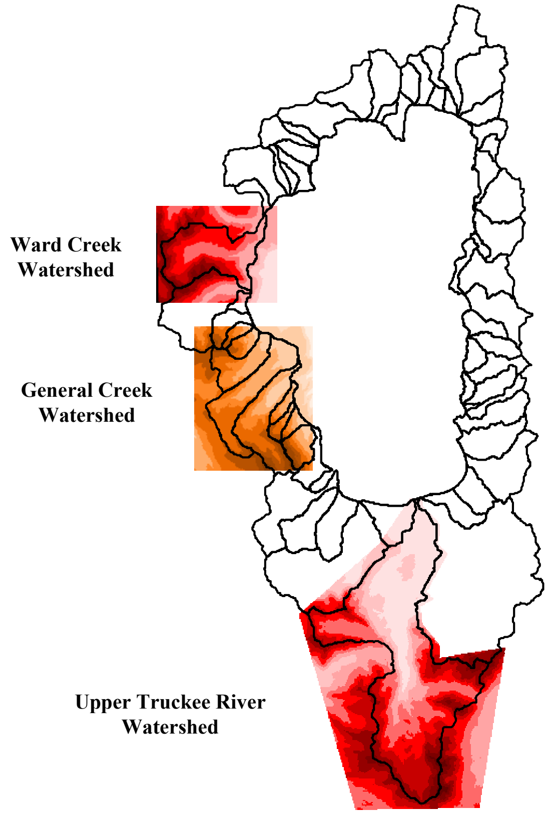

Figure 5-1. The Lake Tahoe watersheds with the digital elevation model (DEM) obtained from USGS at the 10 m by 10 m resolution for the Ward Creek, General Creek, and Upper Truckee River watersheds.

Digitized Soil Maps

The soils GIS layer obtained from the United States Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS) is the Soil Survey Geographic (SSURGO) data base layer based on the NRCS County Soil surveys that is available for the entire Lake Tahoe Basin. From the SSURGO GIS layer, every digitized soil is assigned a mapping-unit symbol, which corresponds to a database of soil characteristics needed for use with AnnAGNPS. This is also obtained from the NRCS. Soils in the Lake Tahoe Basin are too numerous to list or easily show in a figure, but an example of the spatial variability of the digitized soils contained within General Creek watershed is shown in Figure 5-2.

Digitized Landuse Maps

An accurate description of the landuse is critical in defining the impact land-management practices may have on soil erosion. The determination of the historical landuse for large watersheds such as the Lake Tahoe Basin can be difficult without the use of satellite imagery. Although, local information based on documented aerial photography can be used, this often requires considerable time in analyzing and digitizing the data. Various sources were used to derive the best description of the landuse in Lake Tahoe watersheds by the amount and location of the various types of vegetation.

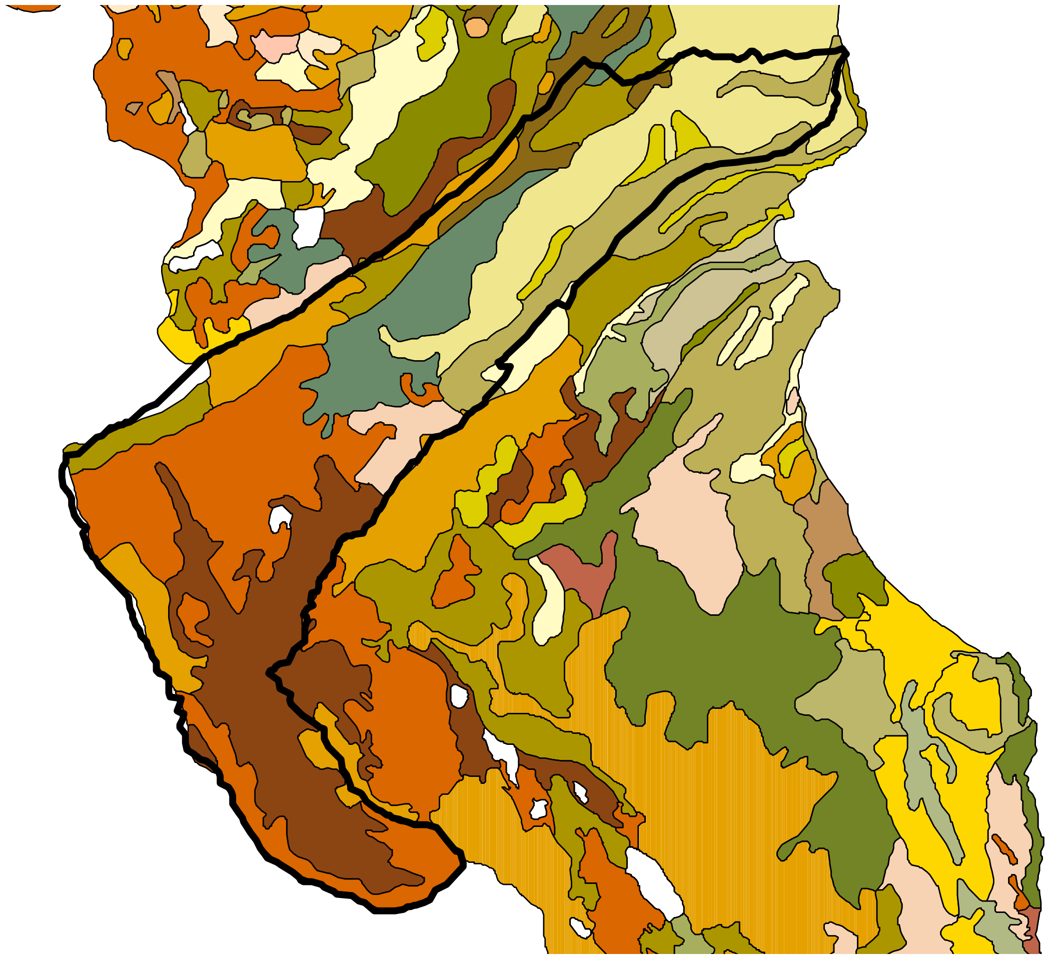

Figure 5-2. The Soil Survey Geographic (SSURGO) GIS layer for General Creek watershed obtained from the USDA-NRCS.

There were two types of landuse information available for Lake Tahoe. One was the National Land Cover Data (NLCD) and the other was from the University of California at Davis, Tahoe Research Group (TRG). Generally, the NLCD data provided good definition of the non-urban areas, while the TRG data provided good definition of the urban areas. For this study a combination of both landuse GIS layers were used to determine the appropriate landuse to apply to each AnnAGNPS cell. NLCD data were ultimately used for the entire watershed, with the exception of urban areas, which were defined by TRG data. The NLCD was developed by the Multi-Resolution Land Characteristics (MRLC) Consortium that was sponsored originally in 1992 by various federal agencies. The data can be obtained at the Internet Web address: http://www.epa.gov/mrlc/nlcd.html.

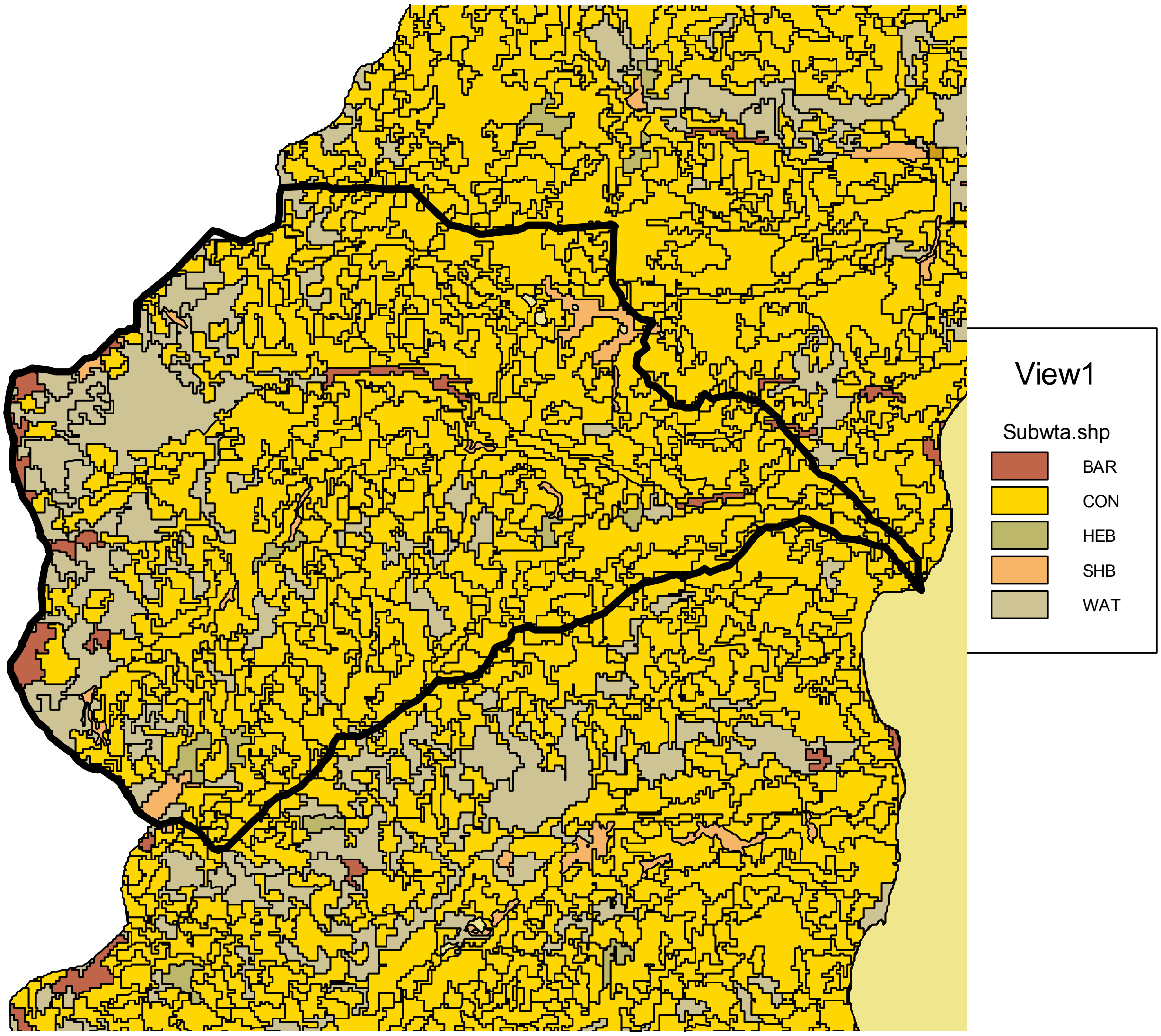

Figure 5-3. The National Land Cover Data (NLCD) based on images from 1990-1993 within the Ward Creek Watershed boundary.

Land-cover was mapped using general land cover classes. For example, forest is classified as either, deciduous, evergreen or mixed. Land-cover classification was based on MRLC's Landsat 5 Thematic Mapper (TM) satellite data archive and a host of ancillary sources. For the Lake Tahoe basin images from 1990 to 1993 were used to develop the GIS layer, such as for Ward Creek watershed (Figure 5-3). This is also distributed at the USGS Lake Tahoe Data Clearinghouse web site. The TRG GIS landuse layer for Ward (Figure 5-4) shows considerably more urban area than the NLCD coverage (Figure 5-3).

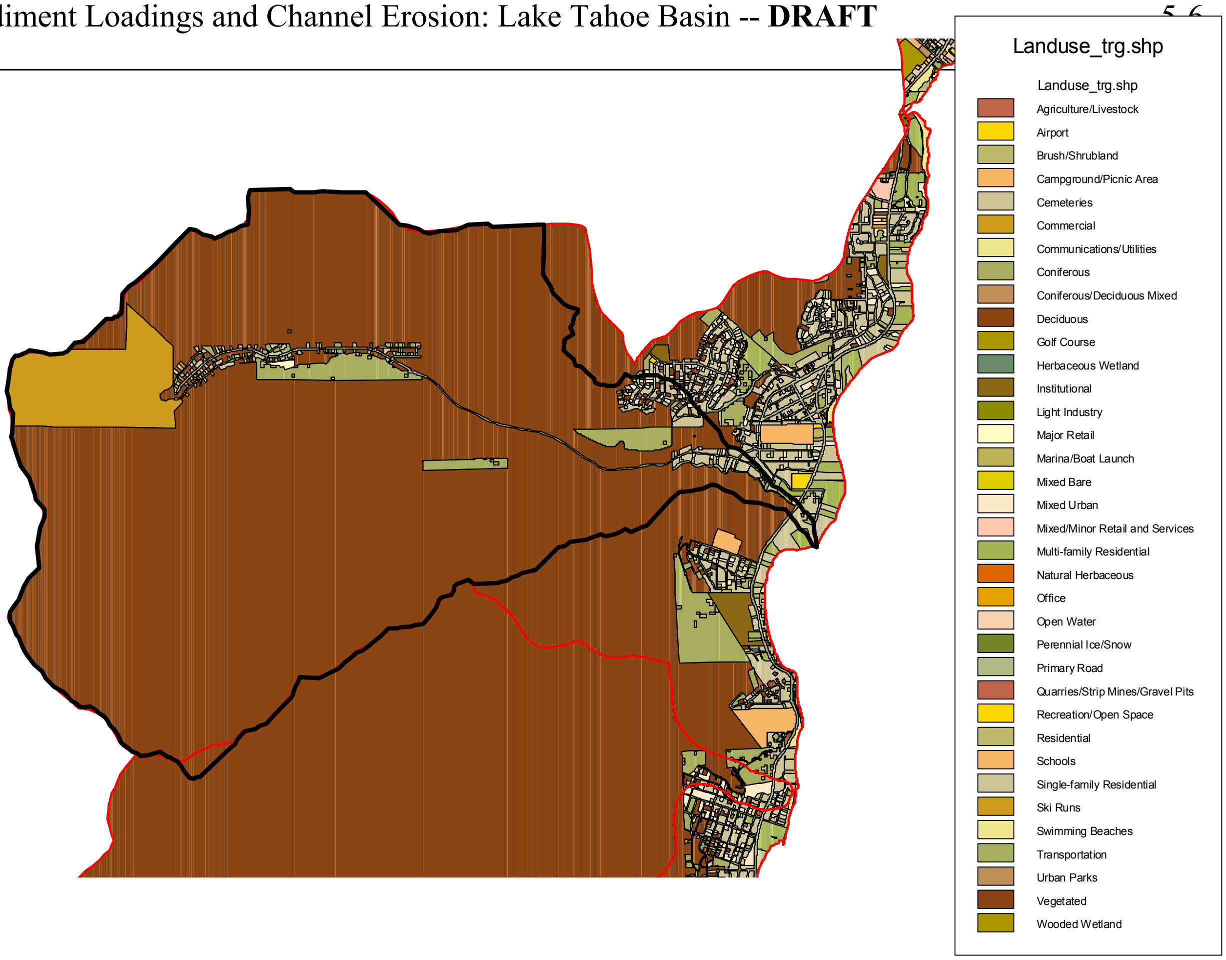

Figure 5-4. The University of California at Davis, Tahoe Research Group (TRG) landuse GIS layer for Ward Creek watershed where the dark brown color represents non-urban areas and the other colors are urban areas.

Additional GIS Layers

Digital Raster Graphics (DRG). Digital Raster Graphics (DRG) are digital copies of 7.5 minute - 1:24,000 topographic maps published by the USGS. The USGS produces their DRG product by scanning paper copies of the map at 500dpi and then re-sampling them to 250 dpi. USGS topographic maps covering Lake Tahoe were likely published over a number of years. The DRGs are output as geotiff image files. The DRGs are very useful in evaluating the location of the watershed boundary and channels generated by TOPAGNPS.

Digital Ortho Quarter Quads (DOQQs). Digital Ortho Quarter Quads (DOQQs) were produced from 23 millimeter by 23 millimeter (9 x 9 inch) film images scaled at 1:40,000 and mosaicked to produce an image in UTM projection for the entire Lake Tahoe Basin. They have ground resolution of one meter and are available for 1992 and 1998. These images can then be used to investigate various features in the watershed such as the location of terraces, gullies, or ponds.

Perennial and Intermittent Streams. The location of perennial and intermittent streams is important in determining if the generated stream network by TOPAGNPS is of a sufficient accuracy to use with AnnAGNPS. The location of streams can also provide information as to whether the watershed boundary has been determined accurately. This can be seen if a stream crosses a watershed boundary, resulting in a problem with the DEM. One technique to improve the accuracy of the location of the watershed boundary and generated streams is to adjust the DEM based on the location of the digitized streams. Whenever a digitized stream would fall onto a DEM raster then the elevation of the DEM raster can be adjusted by a set amount, such as subtracting three meters from the DEM raster value. This would help to ensure that the slope of the streams would be maintained when the TOPAGNPS module generates the stream network. For the Lake Tahoe Basin, the digitized perennial and intermittent streams were obtained from the USGS Lake Tahoe Data Clearinghouse WEB site.

5.2.2 AGNPS Arcview Interface Application

The AGNPS Arcview interface can simplify many of the steps used in developing the input parameters required by AnnAGNPS. The User's Guide for the AGNPS interface details the application of the program. A summary of what was done for the Lake Tahoe watersheds to develop the AnnAGNPS input dataset using the interface is provided in this chapter.

5.2.3 Watershed Segmentation

General Creek Watershed

Drainage Boundary. A determination of the drainage boundary for General Creek watershed is critical before proceeding to other issues, such as using the landuse and soils GIS layers to determine the attribute identifier from each layer. Having an accurate watershed boundary focuses the area of concern so all of the important watershed characteristics can be examined. Using the AGNPS Arcview interface, which accesses the TOPAGNPS files, and the DEM, the watershed boundary file was produced. Additional files for use with AGNPS were also produced, but the use of those will be discussed in later sections. The first step in this process is to determine the watershed outlet.

For the General Creek watershed, the outlet coincides with the mouth of General Creek as it flows into Lake Tahoe. The exact location of the outlet in terms of the position within the DEM was determined using the perennial streams and the DRG. This also allows the DEM to be reduced in size by clipping the drainage area that includes only General Creek watershed (Figure 5-1) using the AGNPS Arcview Interface. This reduces the computational time needed when using TOPAGNPS and displaying the final determinations with Arcview. The DEM was clipped based on the location of the confluence of General Creek and Lake Tahoe, and the drainage area that would flow into the farthest upstream channel locations. Elevations were then converted to meters. The watershed outlet location used by TOPAGNPS was determined by viewing the DRG and DOQQ layers with digitized streamflow locations for the entire General Creek watershed DEM, and using the "Step 2 Select watershed Outlet" menu item of the Interface with the "Interactively Select Outlet" option. Once the outlet was determined, AGNPS Arcview Interface Steps 3-6 were performed to generate the topographic parameters used by AnnAGNPS. The watershed boundary along with the generated stream network, and other associated files were also produced for use in analyzing the data for any noticeable problems.

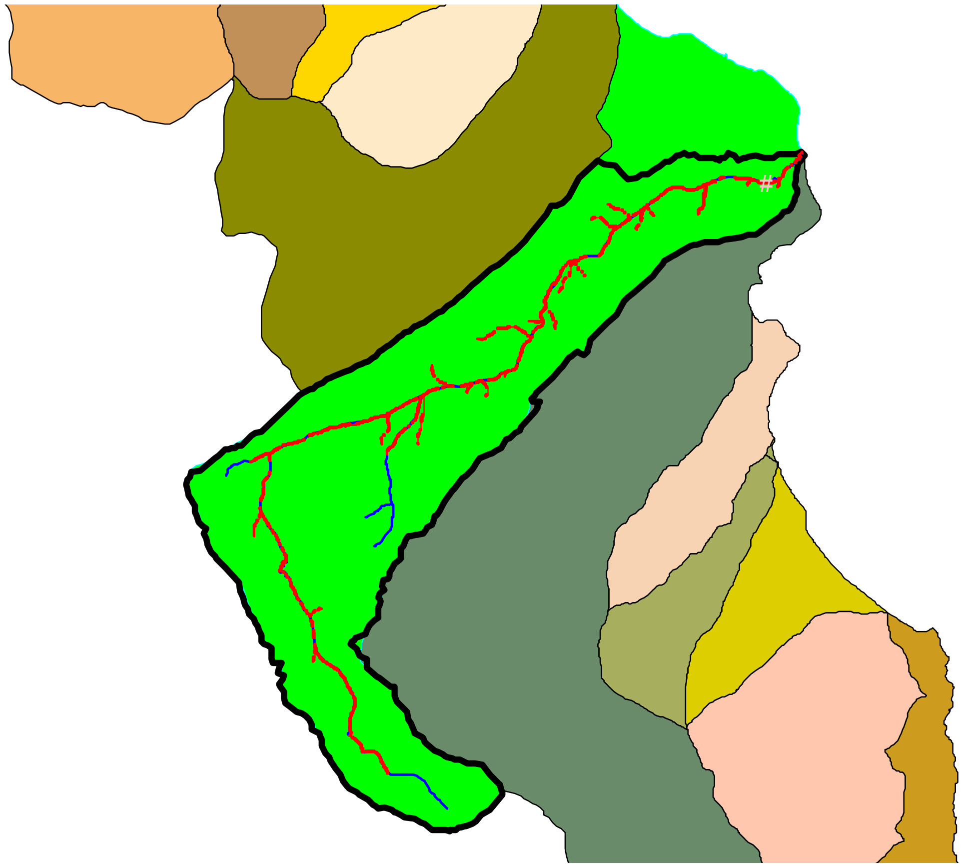

Figure 5-5. The General Creek generated watershed boundary (black line), digitized boundary (light green area), generated stream network (red line), and digitized stream network (blue line).

From previous experience, the location of the stream network generated by TOPAGNPS may not define very well the location of the major confluences as observed from the digitized streams. Thus, a modification of the clipped DEM was made based on the location of the digitized perennial and intermittent stream locations. This would provide information within the DEM concerning the location of concentrated flows and the generated stream network that would likely produce a stream network similar to the digitized stream network (Figure 5-5).

Subdrainage Areas: AnnAGNPS Cells. The determination of the subdrainage areas of the General Creek watershed into AnnAGNPS cells was performed based on the spatial variation of landuse and the location of the digitized stream network. The watershed was subdivided into a significant number of cells to reflect appropriate landuse. The process started with an assumption of the critical source area (CSA) and minimum source channel length (MSCL) required with the use of TOPAGNPS. An initial 100 hectare CSA and 300 m MSCL values were selected to produce AnnAGNPS cells that are of significant size that individual AnnAGNPS cells can be identified for further subdivision. The process of starting with the generation of AnnAGNPS cells with large drainage areas and working to subdivide only those areas of major concern to the user's satisfaction provides the simplest approach to capturing the main features of the watershed.

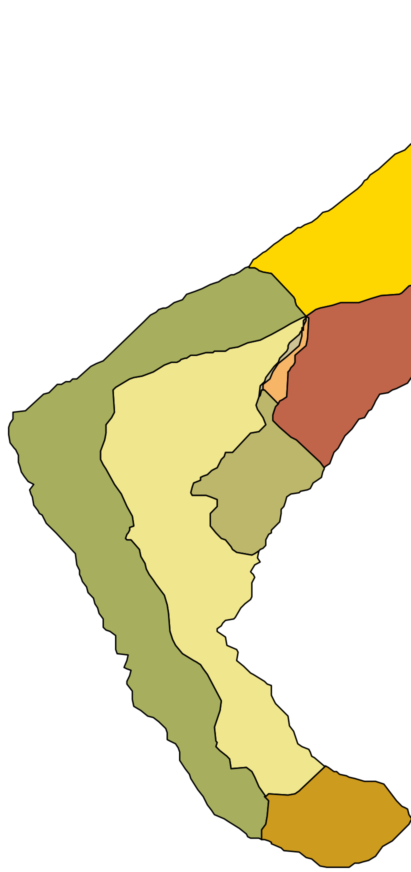

Figure 5-6. The first trial of the generation of AnnAGNPS cells for General Creek watershed.

The initial subdivision produced 8 AnnAGNPS cells distributed throughout the watershed (Figure 5-6). Since landuse areas did not appear to be adequately characterized, various AnnAGNPS cells were selected for further subdivision using one of four various TOPAGNPS regions defined within the generation of the network region generation file (ntgcod.inp) (Figure 5-7). The final subdivision of General Creek watershed with TOPAGNPS produced 126 AnnAGNPS cells based on four TOPAGNPS regions using CSA and MSCL values provided in Table 5-1, with an associated stream network of 52 reaches to produce the final subwatershed layer (Figure 5-8).

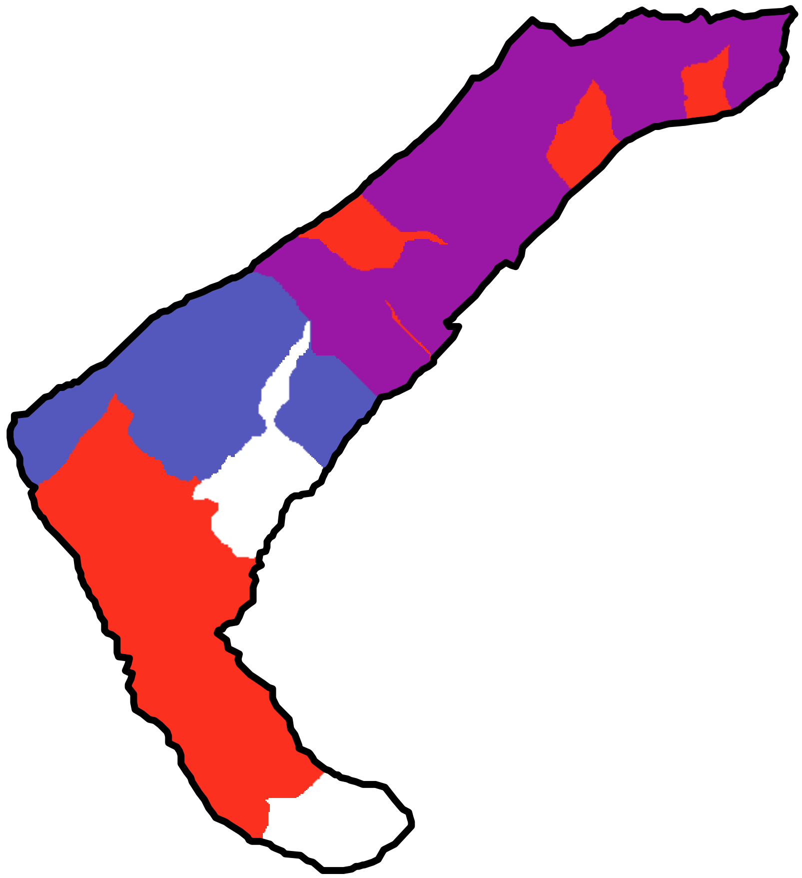

Figure 5-7. The delineation of TOPAGNPS regions for use with various CSA and MSCL values within TOPAGNPS to develop a more detailed subdivision of the watershed for use as AnnAGNPS cells. Region 1 is indicated with white, Region 2 with blue, and Region 3 with red, and Region 4 is purple.

Table 5-1. The TOPAGNPS critical source area (CSA) and minimum source channel length (MSCL) parameters used for each of the four regions defined for the final subdivision of the watershed into AnnAGNPS cells.

TOPAGNPS CSA and MSCL Region	CSA Parameter (hectares)	MSCL Parameter (meters)
1	100	300
2	50	150
3	25	75
4	10	30

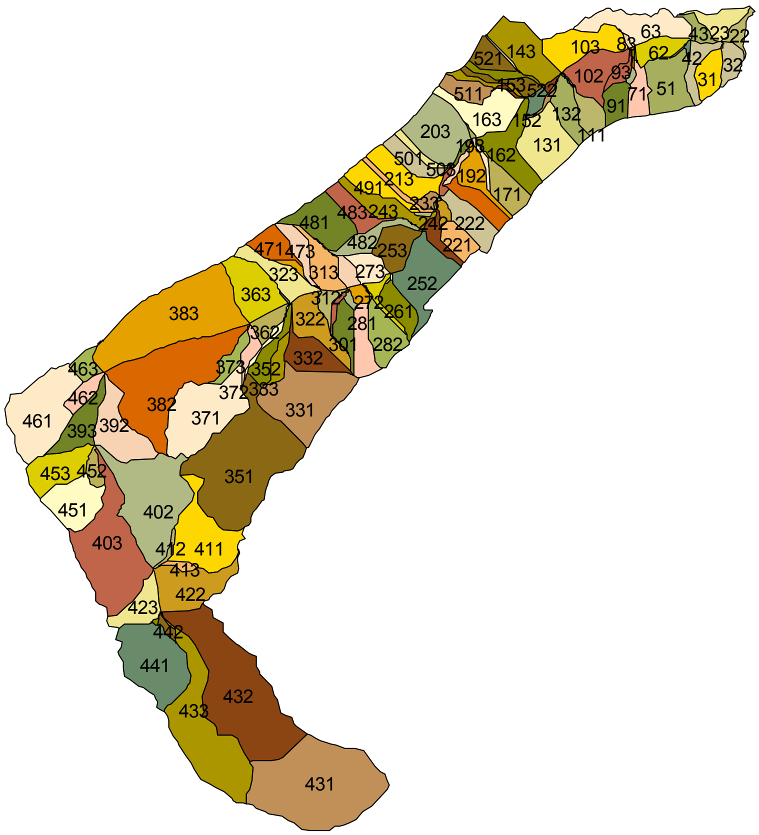

Figure 5-8. The final generation of AnnAGNPS cells used for the General Creek watershed simulations.

<u>Stream Network</u>.

Generated and Digitized Drainage Network. In order to ensure that the process of using TOPAGNPS produced an adequate stream network to link with the CONCEPTS model, the stream network was compared to the digitized location of the perennial and intermittent streams (Figure 5-9). Major confluences of tributaries and the main channel were examined along with the physical location of the channels as observed using the DOQQs. The generated stream network reflected the digitized stream network in most cases.

Location of Tributary Confluences Within the Main Channel. The confluences of tributaries generated by TOPAGNPS that flow into the main channel of General Creek were determined from visual inspection of the generated stream network (Figure 5-10). Each tributary outlet reach number identifier assigned from TOPAGNPS was designated as a point that AnnAGNPS would produce information needed by CONCEPTS for each runoff event that occurred between January 1, 1976 and December 31, 2002. The tributary confluence was then assigned as inflow to the main channel as simulated by CONCEPTS with the tributary information from AnnAGNPS produced in a single file.

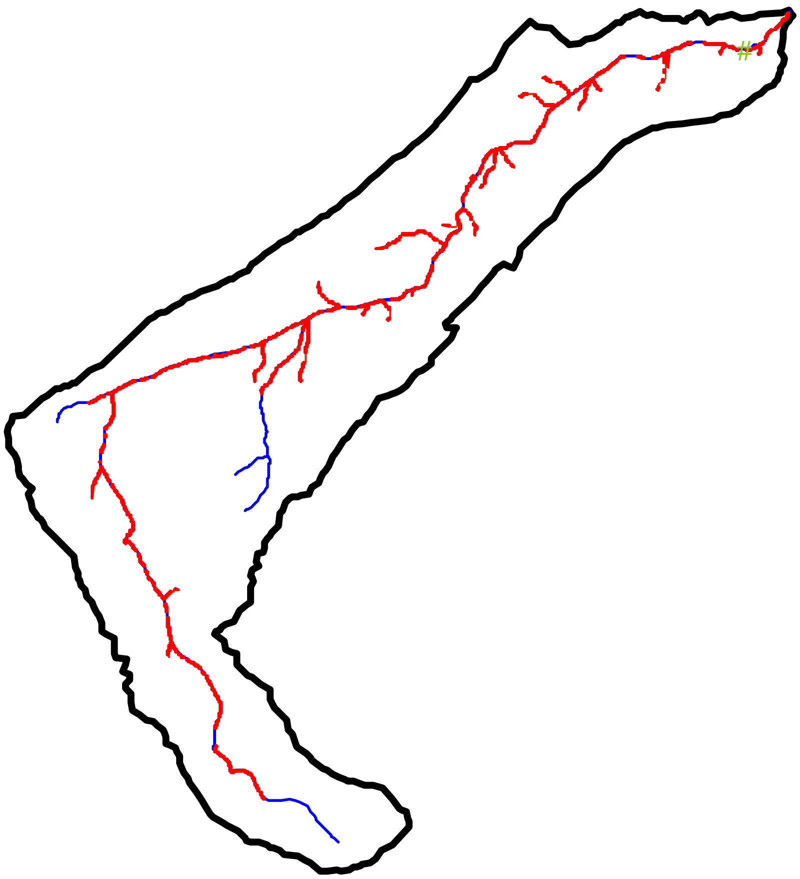

Figure 5-9. The generated stream network (red) in comparison with the digitized streams (blue) with the General Creek watershed boundary (black), plus the location of the gage represented by the green dot at the top of the figure.

Upper Truckee River Watershed

Drainage Boundary. A determination of the drainage boundary for Upper Truckee River watershed follows similar procedures as used for General Creek watershed (Figure 5-11). For Upper Truckee River watershed the outlet coincides with the mouth of Upper Truckee River as it flows into Lake Tahoe. A modification of the clipped DEM was made based on the location of the digitized perennial and intermittent stream locations.

Subdrainage Areas: AnnAGNPS Cells. The determination of the subdrainage areas of the Upper Truckee River watershed into AnnAGNPS cells was performed based on the spatial variation of landuse and the location of the digitized stream network. The watershed was subdivided into a significant number of cells in order to reflect landuse. The initial subdivision produced 73 AnnAGNPS cells distributed throughout the watershed (Figure 5-12). Further TOPAGNPS delineation provided the subdivision shown in Figure 5-13. The final subdivision of Upper Truckee River watershed with TOPAGNPS produced 264 AnnAGNPS cells and an associated stream network of 107 reaches (Figure 5-14; Table 5-2).

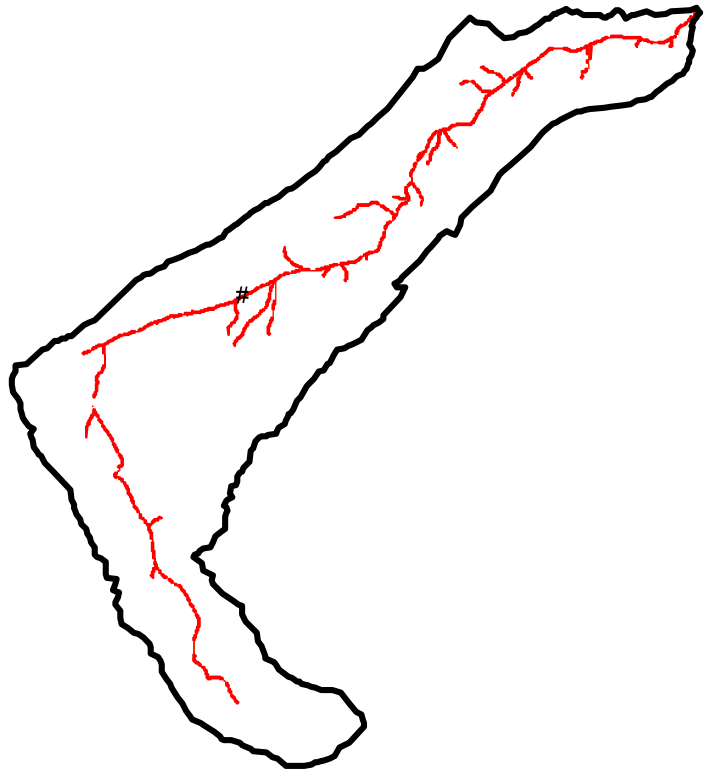

Figure 5-10. The TOPAGNPS generated stream network for General Creek with the main channel simulated by CONCEPTS starting at the black dot and continuing to the outlet.

Figure 5-11. The Upper Truckee River generated watershed boundary (black line) and digitized boundary (shaded area).

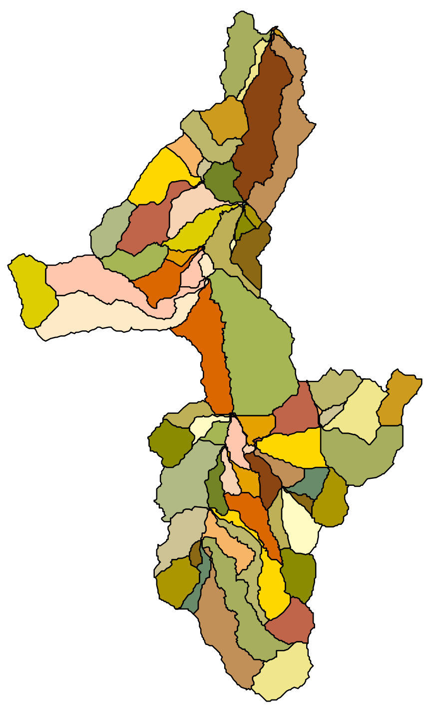

Figure 5-12. The first trial of the generation of AnnAGNPS cells for Upper Truckee River watershed.

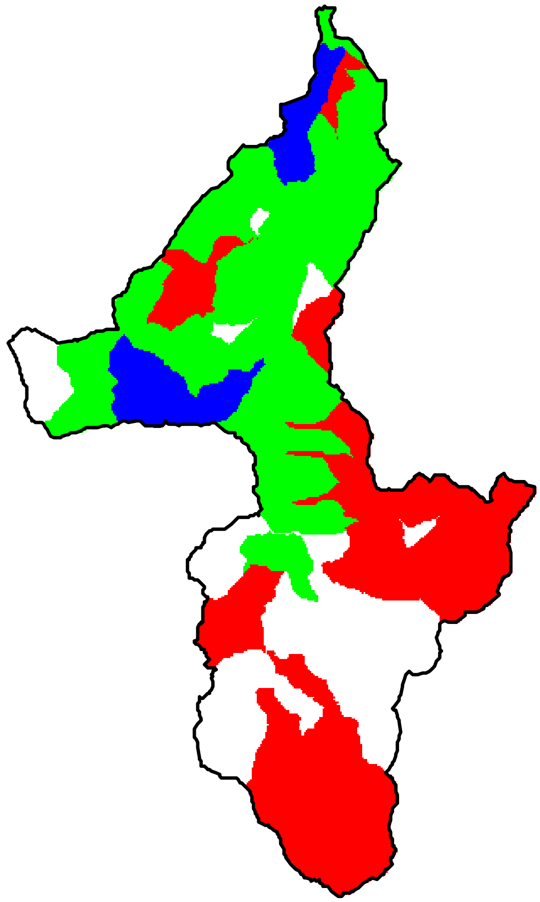

Figure 5-13. The delineation of TOPAGNPS regions for use with various CSA and MSCL values within TOPAGNPS to develop a more detailed subdivision of the Upper Truckee River watershed for use as AnnAGNPS cells. Region 1 is indicated with white, Region 2 with red, and Region 3 with green, and Region 4 is blue.

Table 5-2. The TOPAGNPS critical source area (CSA) and minimum source channel length (MSCL) parameters used for each of the four regions defined for the final subdivision of the Upper Truckee River watershed into AnnAGNPS cells.

TOPAGNPS CSA and MSCL Region	CSA Parameter (hectares)	MSCL Parameter (meters)
1	200	500
2	100	250
3	50	100
4	25	50

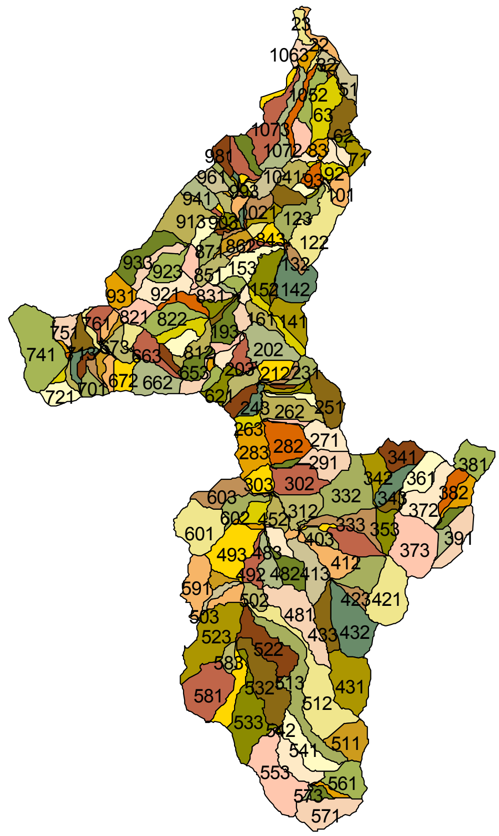

Figure 5-14. The final generation of AnnAGNPS cells used for the Upper Truckee River watershed simulations.

Ward Creek Watershed

<u>Drainage Boundary</u>. A determination of the drainage boundary for Ward Creek watershed follows similar procedures as used for General Creek watershed (Figure 5-15). For Ward Creek watershed the outlet coincides with the mouth of Ward Creek as it flows into Lake Tahoe.

<u>Subdrainage Areas: AnnAGNPS Cells</u>. The determination of the subdrainage areas of the Ward Creek watershed into AnnAGNPS cells was performed based on the spatial variation of landuse and the location of the digitized stream network. The initial subdivision produced 33 AnnAGNPS cells distributed throughout the watershed (Figure 5-16). Various AnnAGNPS cells were selected for further subdivision using one of three various TOPAGNPS regions defined within the generation of the network region generation file (Figure 5-17). The final subdivision of the Ward Creek watershed with TOPAGNPS produced 139 AnnAGNPS cells based on three TOPAGNPS regions using CSA and MSCL values provided in Table 5-3, with an associated stream network of 58 reaches to produce the final subwatershed layer (Figure 5-18).

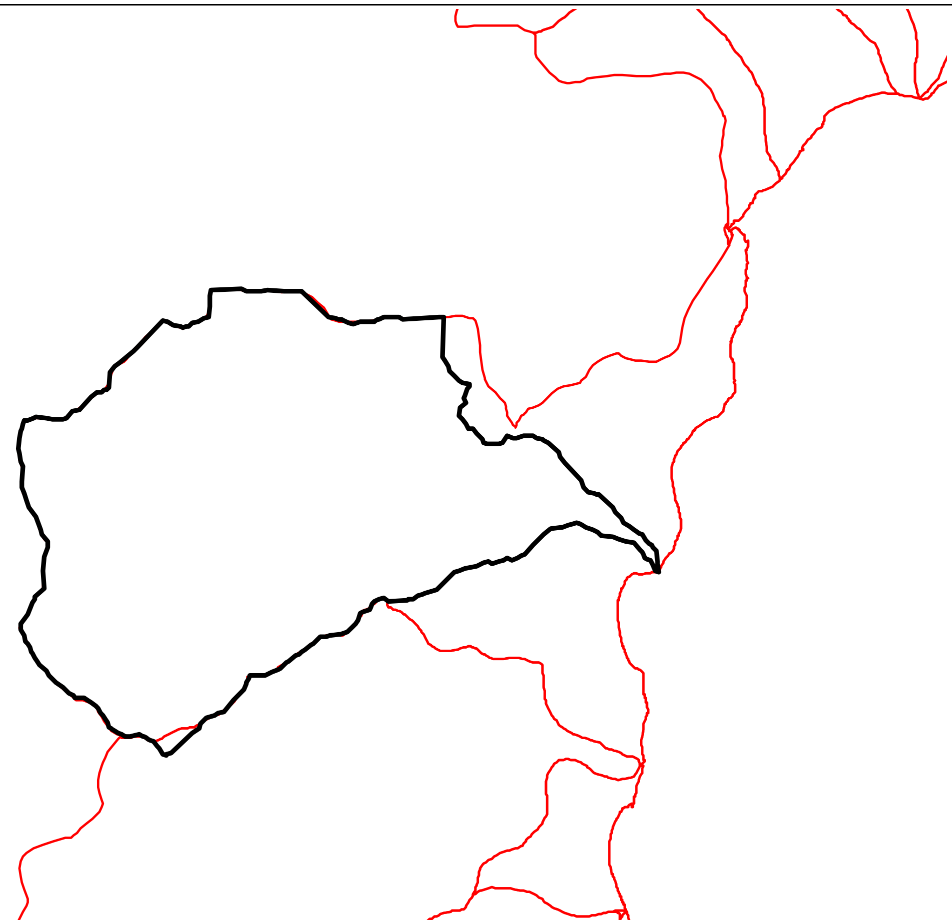

Figure 5-15. The Ward Creek generated watershed boundary (black line) and digitized boundary (red line).

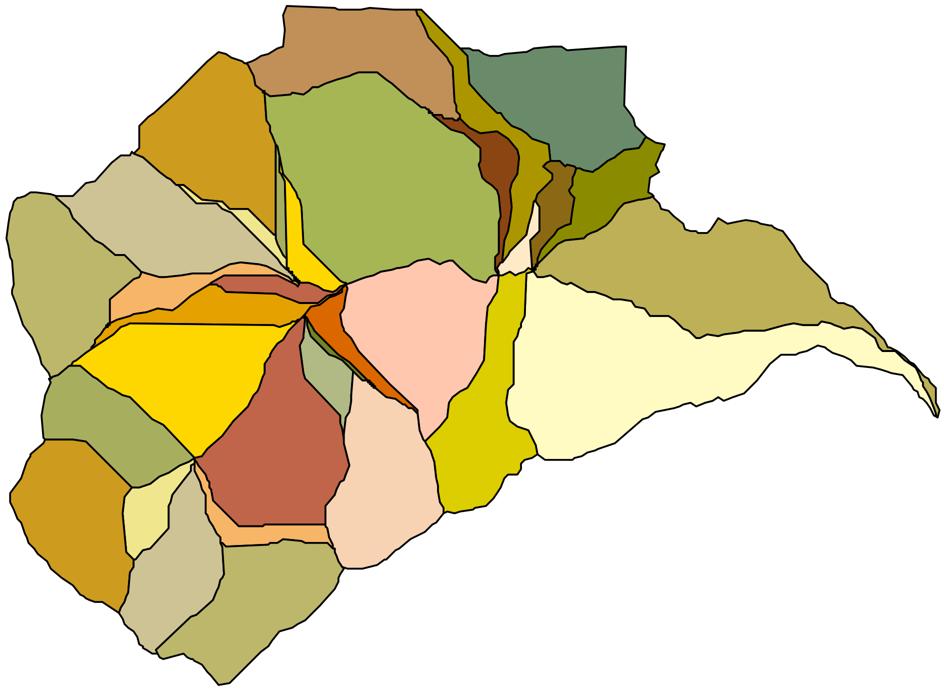

Figure 5-16. The first trial of the generation of AnnAGNPS cells for Ward Creek watershed.

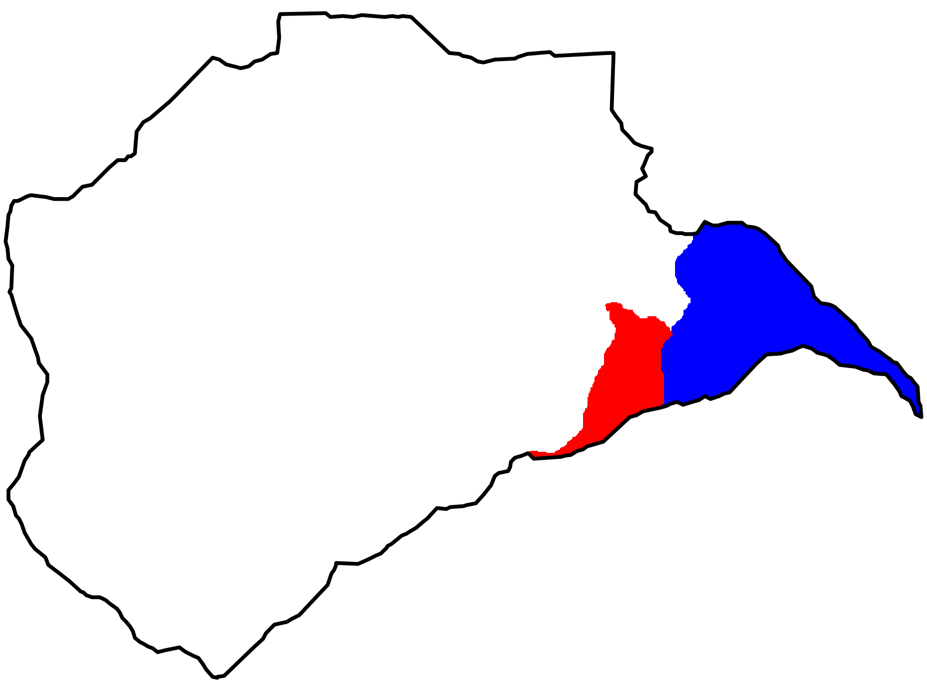

Figure 5-17. The delineation of TOPAGNPS regions for use with various CSA and MSCL values within TOPAGNPS to develop a more detailed subdivision of the Ward Creek watershed for use as AnnAGNPS cells. Region 1 is indicated with white, Region 2 with red, and Region 3 with blue.

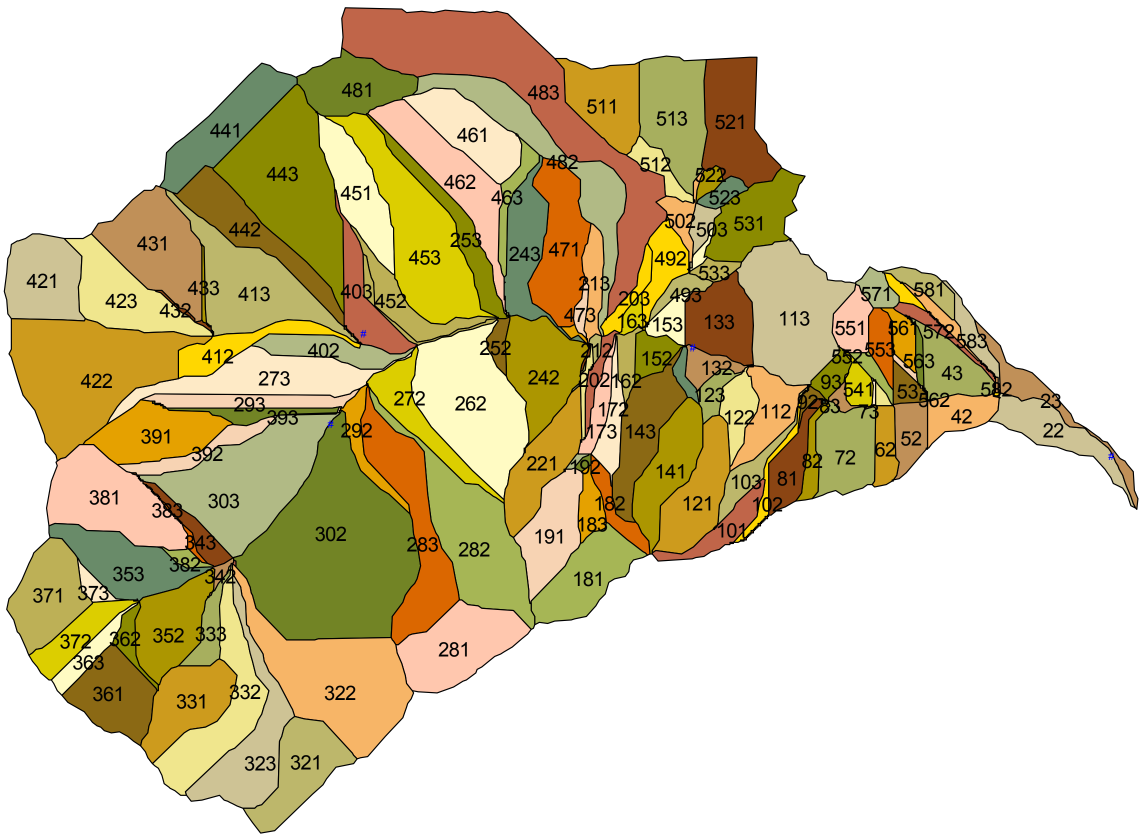

Figure 5-18. The final generation of AnnAGNPS cells used for the Ward Creek watershed simulations.

Table 5-3. The TOPAGNPS critical source area (CSA) and minimum source channel length (MSCL) parameters used for each of the three regions defined for the final subdivision of the Ward Creek watershed into AnnAGNPS cells.

TOPAGNPS CSA and MSCL Region	CSA Parameter (hectares)	MSCL Parameter (meters)
1	25	75
2	10	40
3	5	20

5.2.4 Weather Data

Development of the Climate Database

All weather data was obtained from the nearest NRCS SNOTEL site and was assigned to each of the modeled watersheds (Figure 5-19). Each station was used to determine the individual event information describing measured precipitation and temperature for the years 1976-2002

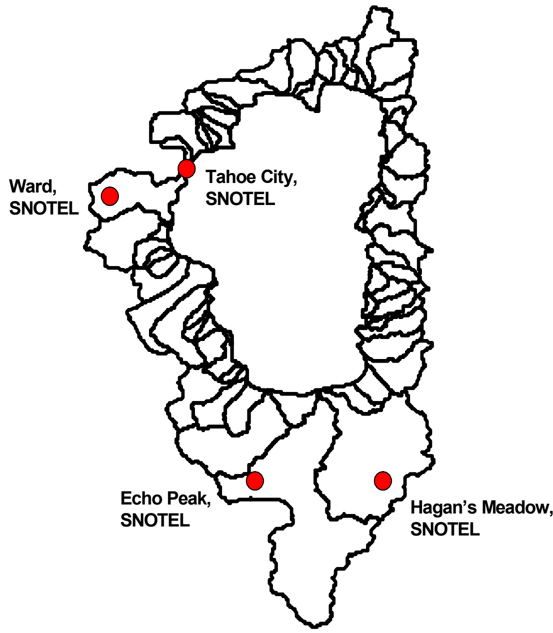

Figure 5-19. Climate stations from the NRCS SNOTEL sites used in the AnnAGNPS simulations.

from the Tahoe City climate station needed for the AnnAGNPS simulation. Climate data, based on numerical simulations conducted by a concurrent research project, were not available for this study.

For the Ward climate station, information from 1980-2002 was available and for Echo Peak and Hagan's Meadow climate stations, only information from 1981-2001 was used. Additional weather data was generated using the GEM climate generator for parameters describing sky cover, dew point, and wind speed, and then actual precipitation and temperature data for those dates replaced the generated values. The annual precipitation measured from each of the climate stations is shown in Figure 5-20. Annual precipitation is generally higher for those climate stations at higher elevations and on the western side of the Lake Tahoe Basin. The climate record for the 50-year simulation was developed for each climate station by repeating the same period of record to create a continuous 50-year climate record. For example, at the Tahoe City climate station, the 1976-2002 record was used for the first 27 years and then 1976-1998 record was used for years after 2002, although the runoff events of January 1 and 2, 1997 were not repeated. A similar approach was used for all of the other climate stations.

Assignment of a Climate Station to an AnnAGNPS Cell

Each climate station represents a point in the Lake Tahoe Basin. Precipitation can be highly variable based on the predominate movement of storms and the elevation at any point. Since there was limited precipitation data in the watersheds, an attempt was made to distribute precipitation in the Upper Truckee and Ward watersheds. Since General Creek watershed did not have a precipitation gage at higher elevations, only the Tahoe City climate station was used.

For the Upper Truckee River watershed, the Echo Peak and Hagan's Meadow climate stations were used and assigned to an AnnAGNPS cell, based on the GIS layer containing the isopluvial lines (Sierra Hydrotech, 1986). For the Ward Creek watershed, the Tahoe City and Ward climate stations were used.

Two additional climate stations were developed for the Upper Truckee River watershed based on the location of the Echo Peak and Hagan's Meadow climate stations within the iso-pluvial line GIS layer. Since the Echo Peak climate station represented a value of 1260 mm on the hypsography and Hagan's Meadow represented a value of 690 mm, two additional climate stations were developed that were a function of each based on the changing hypsography between them. The adjustment in precipitation for the 833 mm to 975 mm file was then a simple increase in Hagan's Meadow precipitation based on the increase in the associated iso-pluvial values, and similarly a decrease in the Echo Peak precipitation for the 975 mm to 1120 mm file. The assignment of the appropriate climate file for each AnnAGNPS cell in the Upper Truckee River watershed is shown in Figure 5-21 and was based on the centroid of the AnnAGNPS cell falling within each isopluvial region defined for each climate file. Water draining from Echo Lake was diverted out of the watershed and thus, was not routed to the Upper Truckee River watershed outlet.

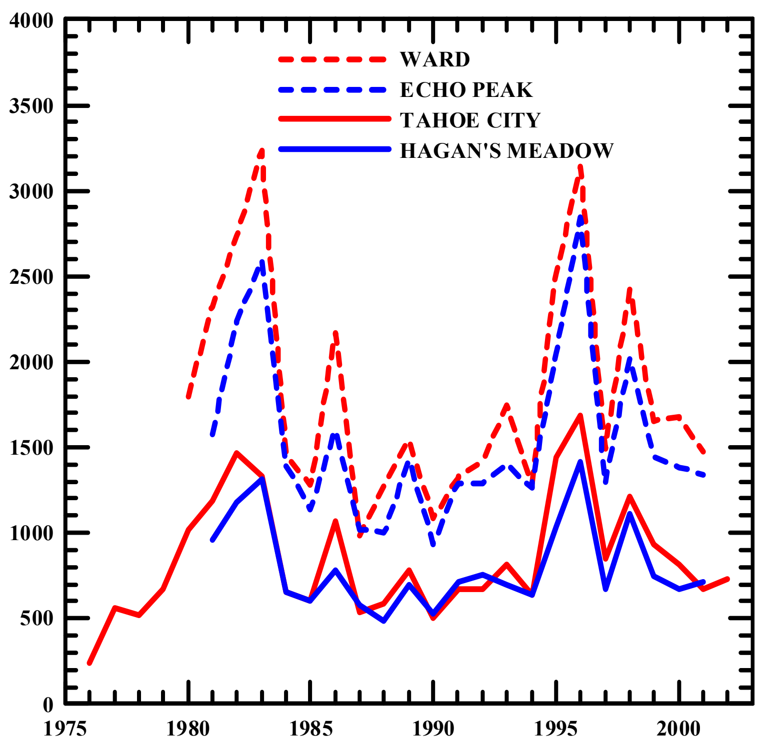

Figure 5-20. Annual precipitation measured at the Ward, Echo Peak, Tahoe City, and Hagan's Meadow climate stations.

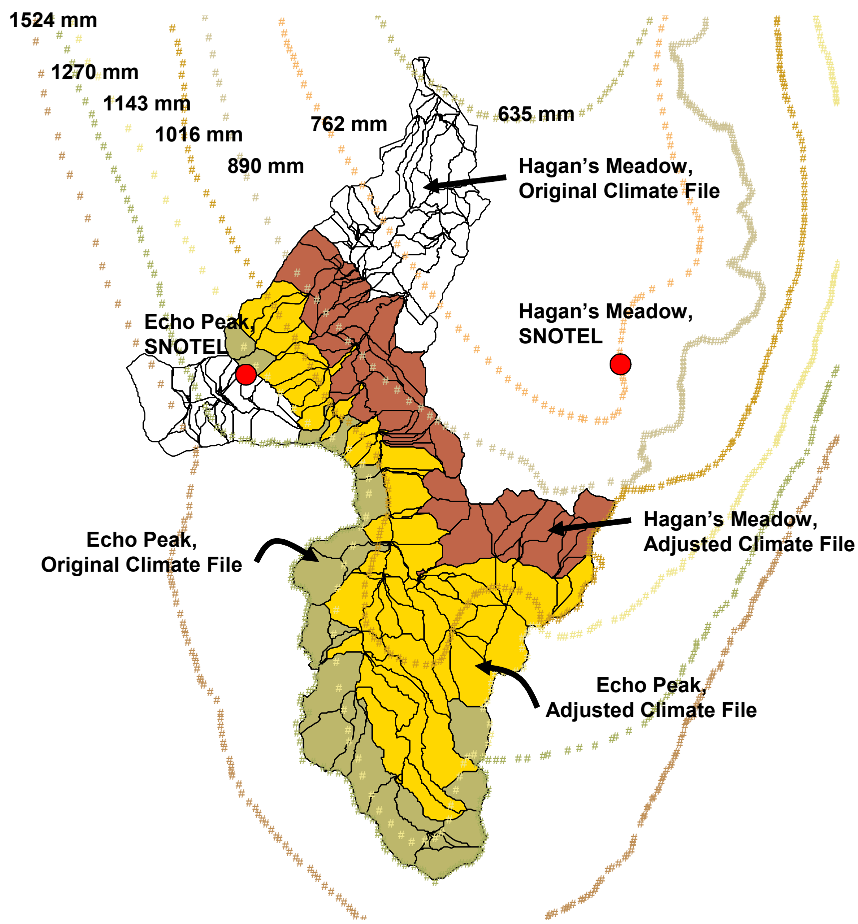

Figure 5-21. Climate files assigned to AnnAGNPS cells based on the isopluvial lines (Sierra Hydrotech, 1986) of Upper Truckee River watershed.

A similar approach was used on Ward Creek watershed for the Ward and Tahoe City climate stations that fell on the 1820 mm and 914 mm values, respectively. The assignment of the appropriate climate file for each AnnAGNPS cell in the Ward Creek watershed is shown in Figure 5-22.

Development of Temperature Lapse Rate

The AnnAGNPS model has the capability to vary temperature by elevation and in a mountainous region this can be critical in defining whether precipitation falls as snow or rain, or runoff occurs as a result of snowmelt. The default lapse rate within AnnAGNPS is the accepted global average decrease of 3.6 degrees Fahrenheit (F) per 1000 feet increase in elevation. For Ward Creek watershed, the Tahoe City and Ward climate stations were used to determine the average lapse rate. Using the corresponding climate period, an average annual lapse rate of 3.9 degrees F was calculated for the Ward Creek Watershed (Figure 5-23).

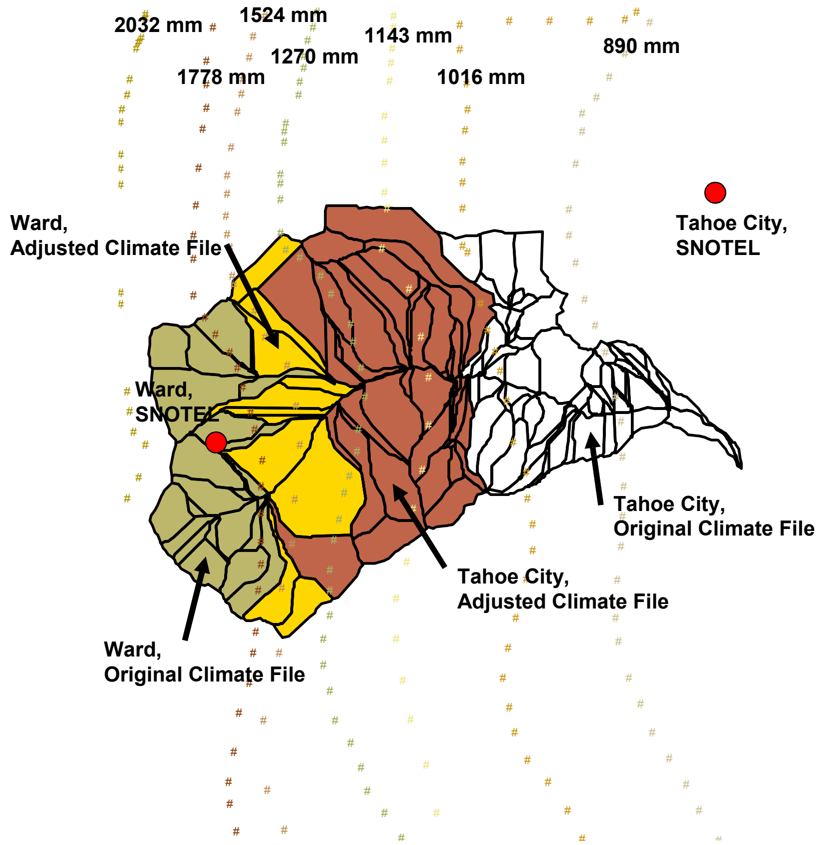

Figure 5-22. Climate files assigned to AnnAGNPS cells based on the iso-pluvial lines of Ward Creek watershed.

For the General Creek and Upper Truckee watersheds, a slightly different approach was used to adjust the timing of snow and rainfall runoff events. Using a 30-year period of mean-daily maximum and minimum temperature data for the Daggett Pass and Glenbrook climate stations, lapse rates were calculated for each day of the year. This was done by taking the average between the average daily maximum and the average daily minimum, and then dividing by the difference in elevation between the stations (930 feet). These data were plotted (Figure 5-24), and the average value during days of below freezing was calculated to be 8.4 degrees F per 1000 feet.

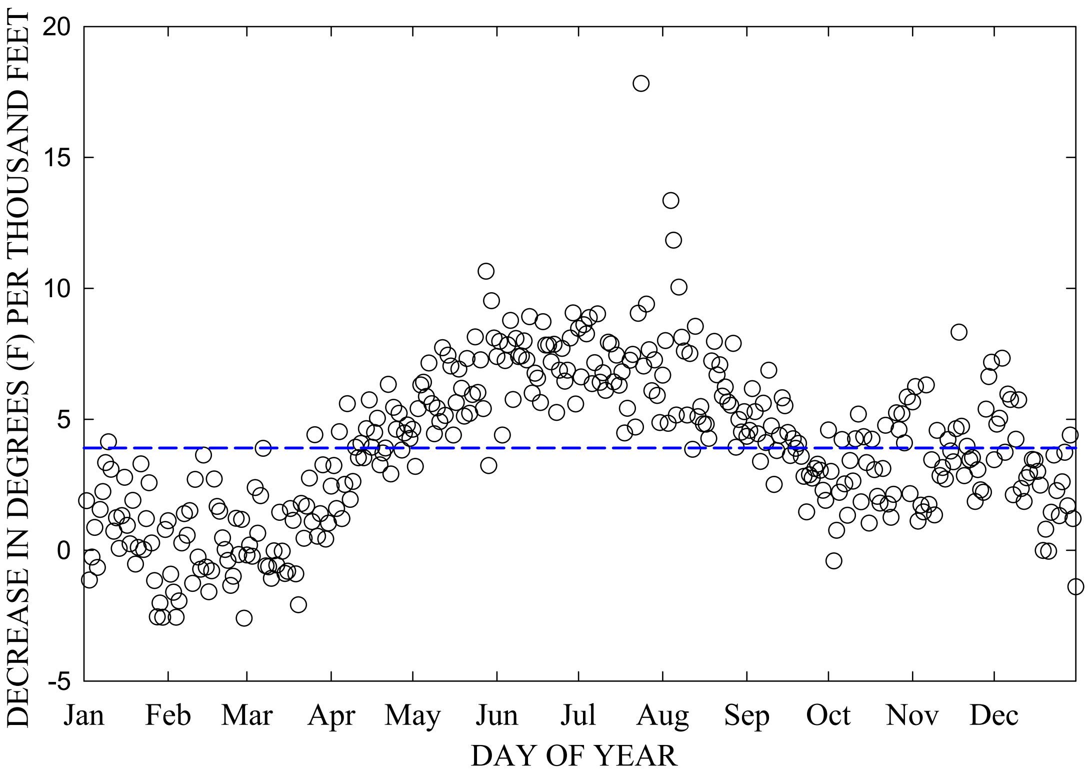

Figure 5-23. Average daily temperature lapse rate between Ward and Tahoe City climate station for Ward Creek watershed.

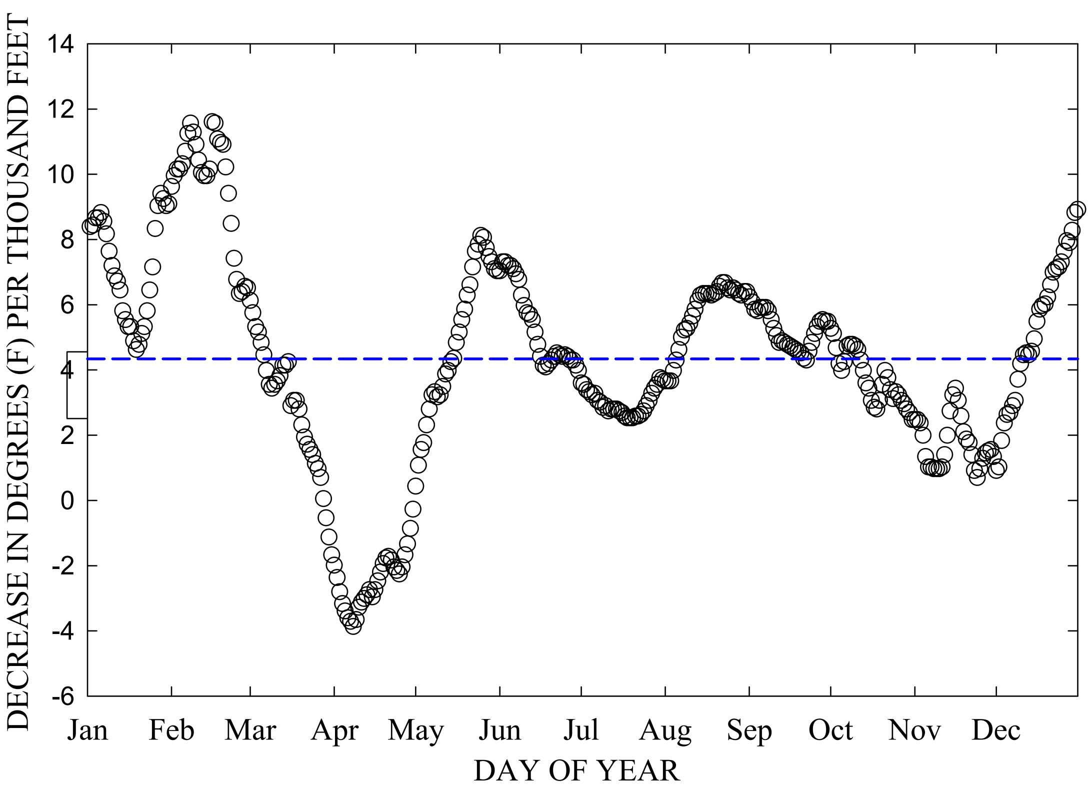

Figure 5-24. Average daily temperature lapse rate between Daggett Pass and Glenbrook climate stations for General Creek and Upper Truckee River watersheds.

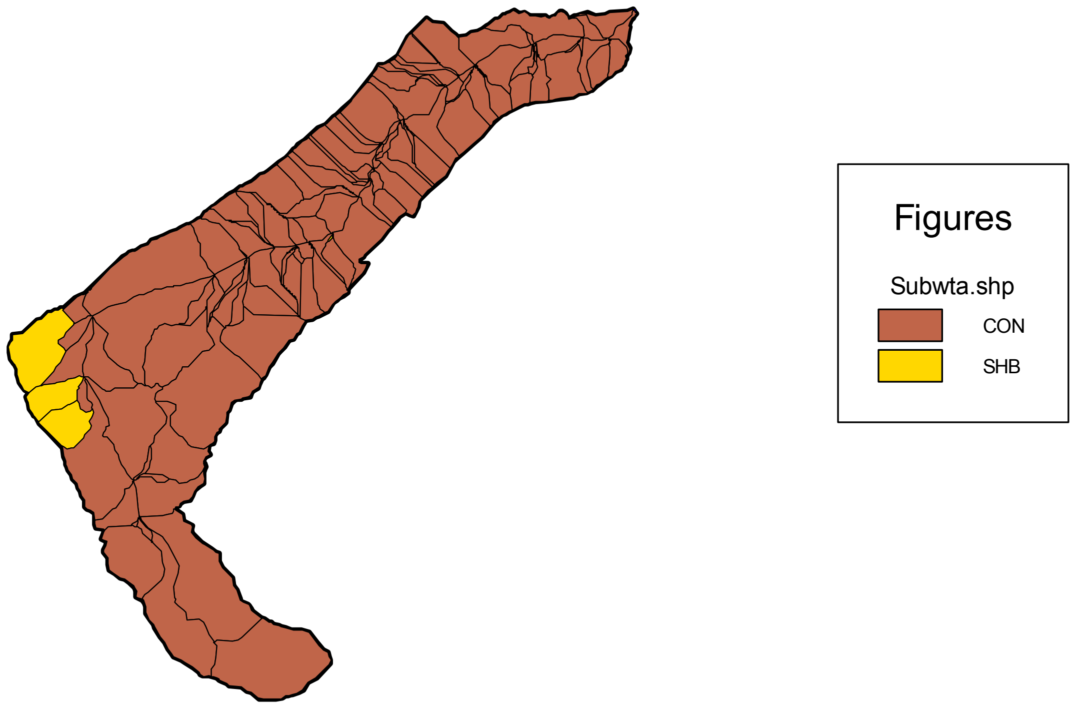

Figure 5-25. Landuse assigned to each AnnAGNPS cell for General Creek watershed. See Table 5-4 for definition of symbols.

5.2.5 Landuse Data

Information pertaining to the landuse of the watershed can be defined for those areas that have a direct impact on runoff and sediment loadings. This information can be defined for best management practices (BMPs) and the assignment of SCS runoff curve numbers associated with specific landuses. The type of landuse assigned to each AnnAGNPS cell was determined using the AGNPS Arcview interface procedure. This procedure assigned a landuse to each cell based on the predominate landuse from the landuse GIS layer and the subwatershed GIS layer associated with the General Creek (Figure 5-25), Upper Truckee River (Figure 5-26), and Ward Creek (Figure 5-27) watersheds, respectively.

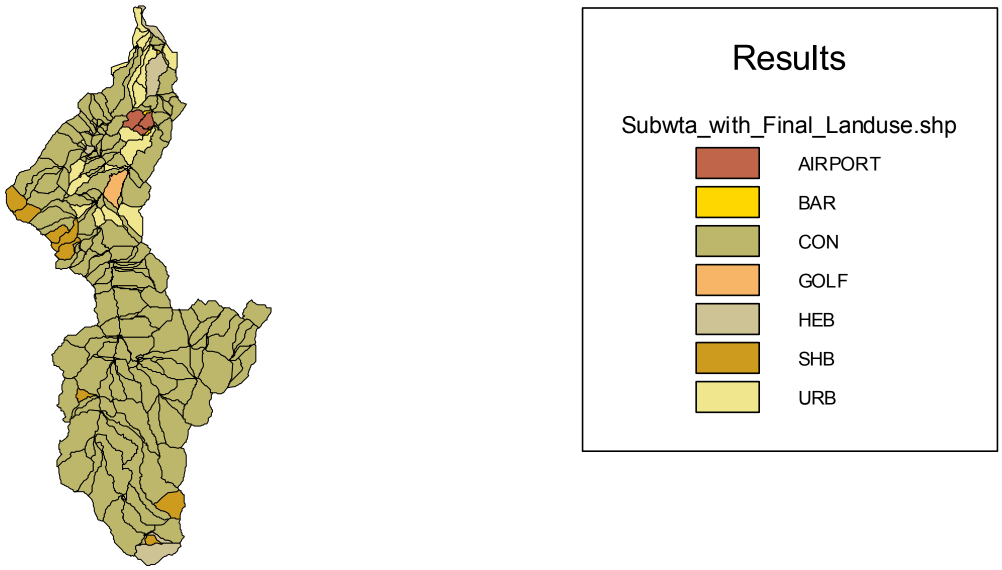

Figure 5-26. Landuse assigned to each AnnAGNPS cell for Upper Truckee River watershed. See Table 5-4 for definition of symbols.

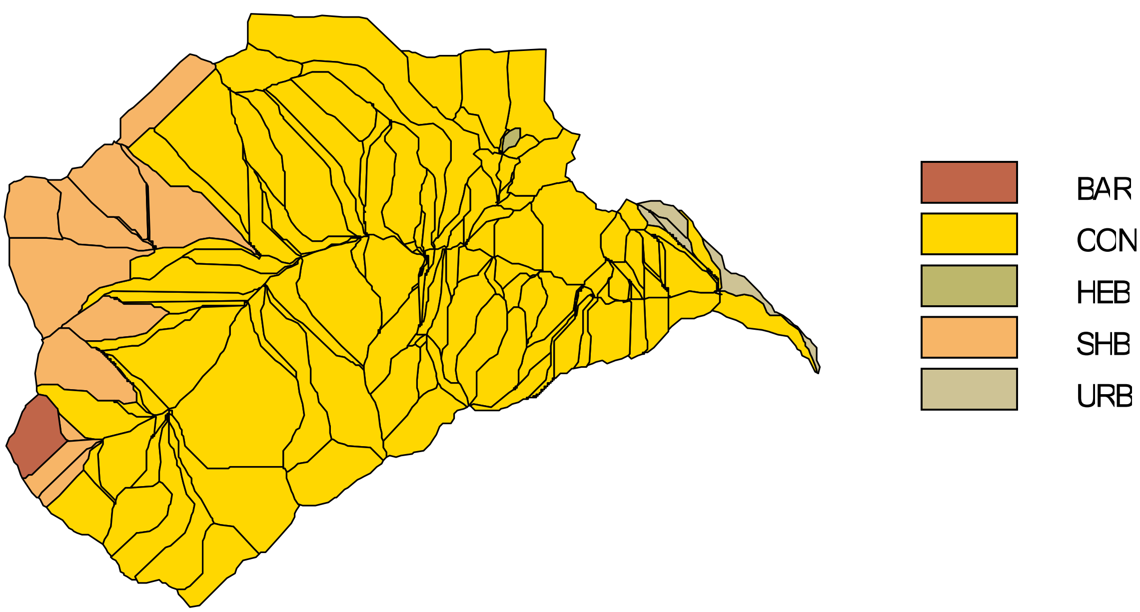

Figure 5-27. Landuse assigned to each AnnAGNPS cell for Ward Creek watershed. See Table 5-4 for definition of symbols.

Soil Conservation Service (SCS) Runoff Curve Numbers Associated with Watershed Characteristics

The Soil Conservation Service (SCS) runoff curve number (CN) is a key factor in obtaining an accurate prediction of runoff and sediment yields. Curve numbers were selected based on the National Engineering Handbook, Section 4 (USDA, Soil Conservation Service, 1985). The SCS CN's used in the model simulation are listed in Table 5-4 and are based on typical values used by NRCS for the land cover classes present in the watersheds. Additional curve numbers were selected for airport and golf conditions to represent those scenarios in the simulation. Each cell assumes that the area within the cell is defined homogeneously throughout the cell.

Table 5-4. SCS curve numbers for the Lake Tahoe Basin watershed simulations by land cover class.

Land Cover Class	Curve Number			
	Hydrologic soil group			
	A	B	C	D
BAR, Fallow Bare soil	77	86	91	94
HEB, Grassy fields, Fair	32	43	60	70
SHB, Shrubs Poor	36	50	68	76
CON, Conifer Forest Good	30	55	70	77
AIRPORT, Some paved roads	83	89	92	93
GOLF	89	92	94	95
URB, Urban, Commercial, and Business	89	92	94	95

5.2.6 Soil Properties

Within the Lake Tahoe Basin there are 73 separate soil types identified from the soil GIS layer. The dominant soils are sandy to sandy loam with many areas defined entirely as rock outcrops. Most of the soils information was derived from the NRCS Soils 5 database. Input parameters that had no impact on soil erosion were set using default parameters. These included parameters such as the soil initial organic nitrogen ratio, which was set based on AnnAGNPS guidelines as 500 PPM for the top layer and 50 PPM for the subsequent layers. The soil assigned to each AnnAGNPS cell was based on the predominant soil type within each AnnAGNPS cell.

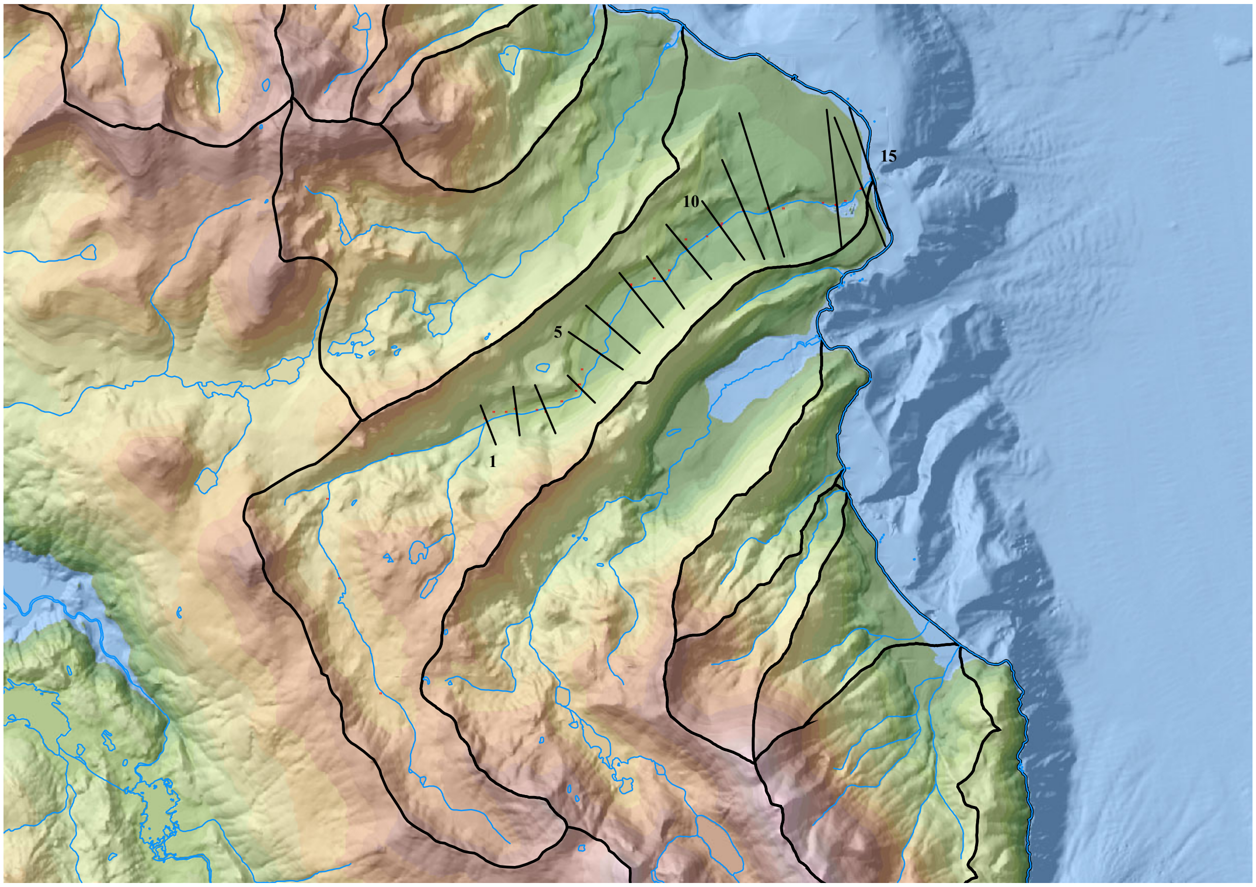

Figure 5-28. Modeling reach and cross section locations along General Creek. Cross section transects are shown in black.

5.3 CONCEPTS Model Setup

5.3.1 Modeling Reach and Parameters

General Creek

Modeling Reach. The modeling reach of General Creek extends from the mouth of the channel (river km 0.01) to river km 6.80 (Figure 5-28). The water and sediment loadings into the modeling reach are provided by the watershed model AnnAGNPS. The modeling reach is composed of 15 cross sections (Figure 5-28). These cross sections are hereafter referred to as cross sections “1” through “15,” where “1” is the most upstream cross section and “15” is the most downstream cross section. The cross sections were surveyed during the data collection campaign in the fall of 2002 (see section 2.2), except for cross section 8. Cross section 8 is cross section “85” surveyed in 1983 by Nolan and Hill (1991). Cross sections 2, 4, 6, and 13 correspond to cross sections “55,” “60,” “70,” and “90” surveyed in 1983 by Nolan and Hill (1991). The latter cross sections will be hereafter referred to as NH55, NH60, NH70, and NH90.

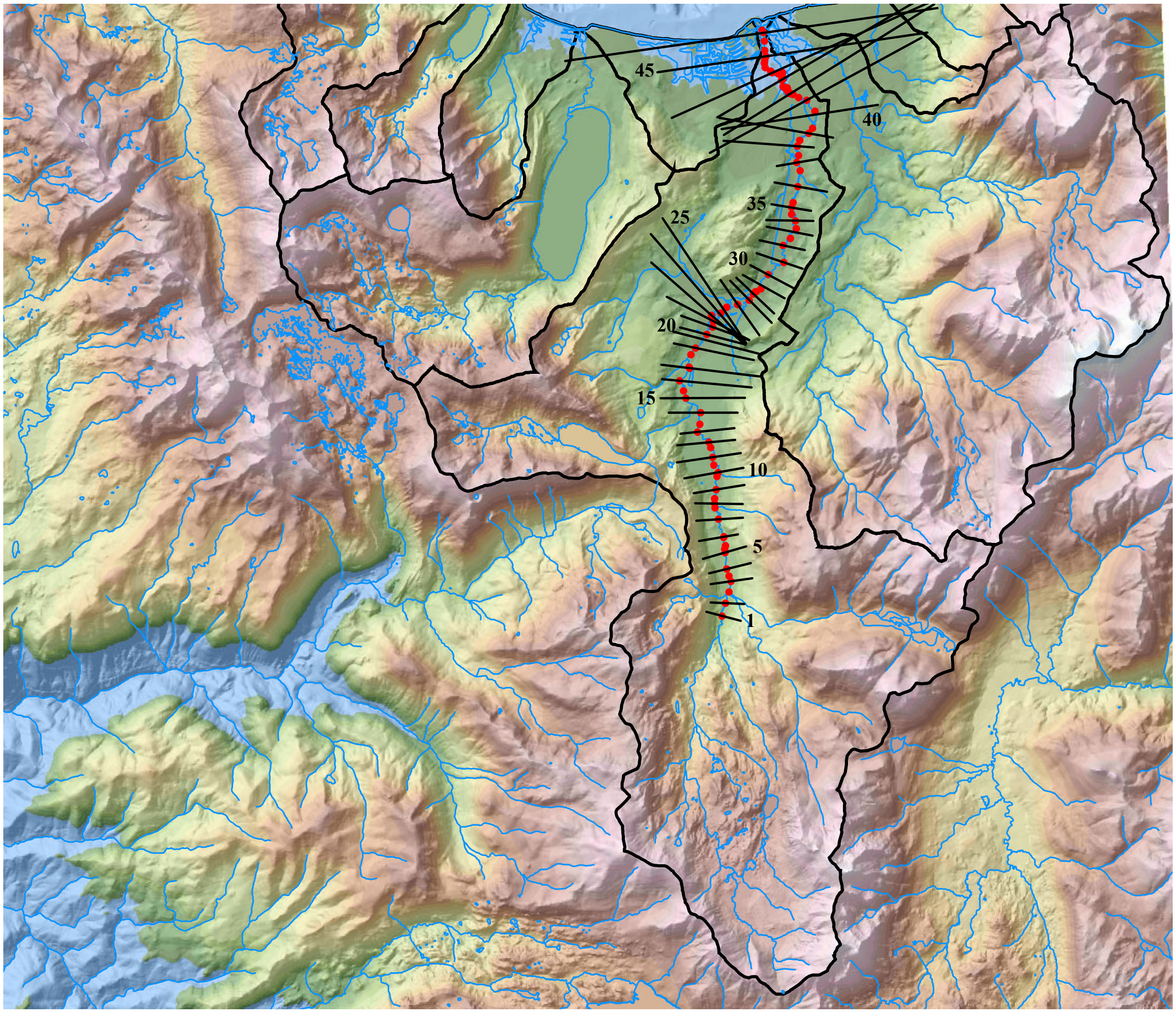

Figure 5-29. Modeling reach and cross section locations along the Upper Truckee River. Cross section transects are shown in black.

Physical Properties. Roughness values were assigned to bed, bank, and floodplain sections of each cross section based on visual inspection of the channel and following guidelines set forth by Aldridge and Garrett (1973) and Jarrett (1985). Bed- and bank-material composition and properties at each cross section were provided by local sediment samples and BST tests (section 2.3). Streambank materials have an average silt/clay composition of 10% (46 samples). In case these data were locally unavailable, data collected at the nearest similar site were used. Table G-1 in the appendix lists the data used at each cross section.

Upper Truckee River

Modeling Reach. The modeling reach along the Upper Truckee River extends from the mouth of the channel (river km 0.38) to river km 24.19 (Figure 5-29). The water and sediment loadings into the modeling reach are provided by the watershed model AnnAGNPS. The modeling reach is composed of 46 cross sections (Figure 5-29). These cross sections are hereafter referred to as cross sections “1” through “46,” where “1” is the most upstream cross section and “46” is the most downstream cross section. Cross sections “1” (river km 24.19) through “28” (river km 10.84) were surveyed during the data collection campaign in the fall of 2002 (see section 2.2). Cross sections “19” (river km 13.70) through “26” (river km 11.68) were surveyed by the California State Parks repeatedly between 1992 and 2001. Cross sections “29” (river km 10.56) through “41” (river km 3.37) were surveyed by Mussetter Engineering in 2001. Cross sections “42” (river km 2.77) through “46” (river km 0.38) were surveyed by Entrix Incorporated in 2001.

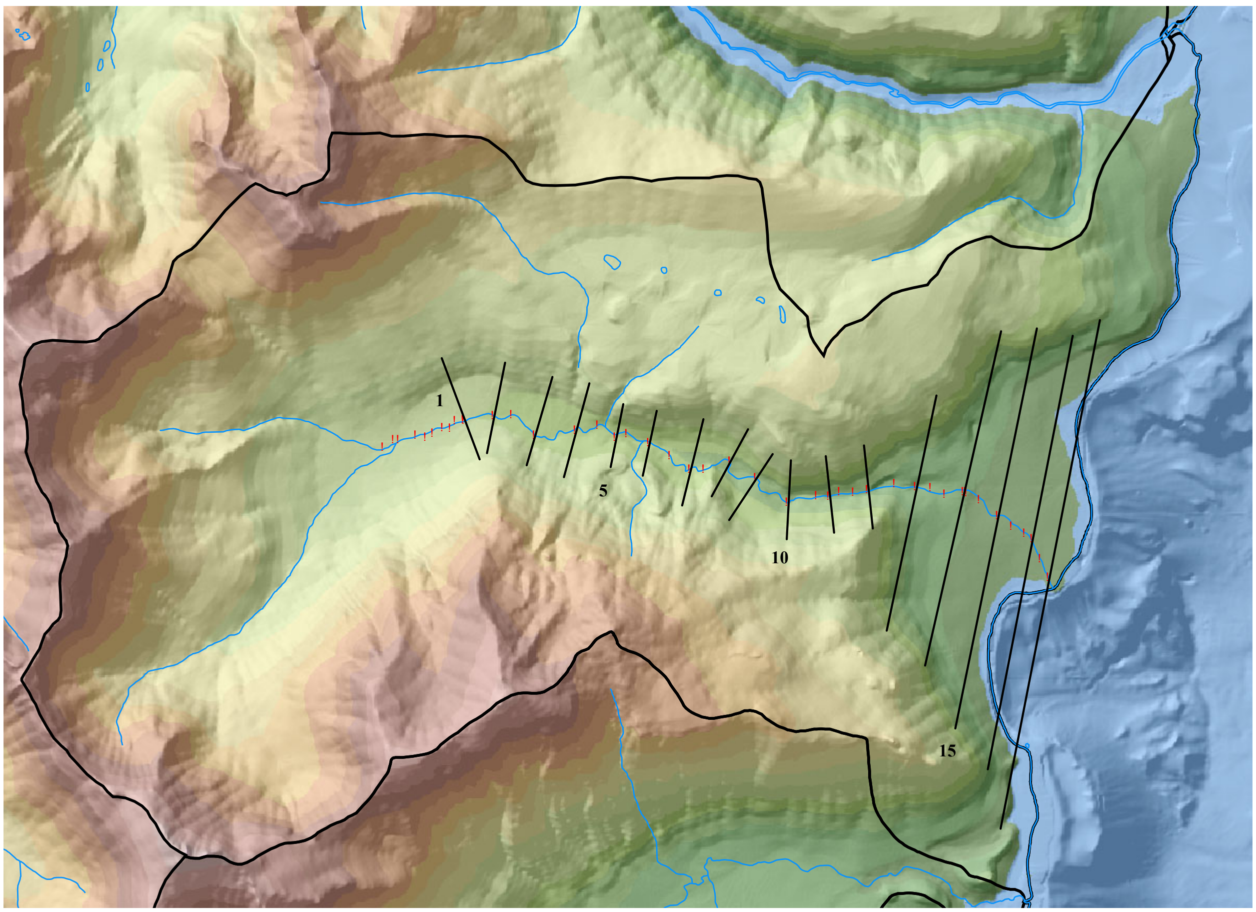

Figure 5-30. Modeling reach and cross section locations along Ward Creek. Cross section transects are shown in black.

Physical Properties. Roughness values were assigned to bed, bank, and floodplain sections of each cross section based on visual inspection of the channel and following guidelines set forth by Aldridge and Garrett (1973) and Jarrett (1985). Bed- and bank-material composition and properties at each cross section were provided by local sediment samples and BST tests (section 2.3). The average silt/clay composition of the streambanks throughout the modeled reach is 14%. In case these data were locally unavailable, data collected at the nearest similar site were used. Table G-2 in the appendix lists the data used at each cross section.

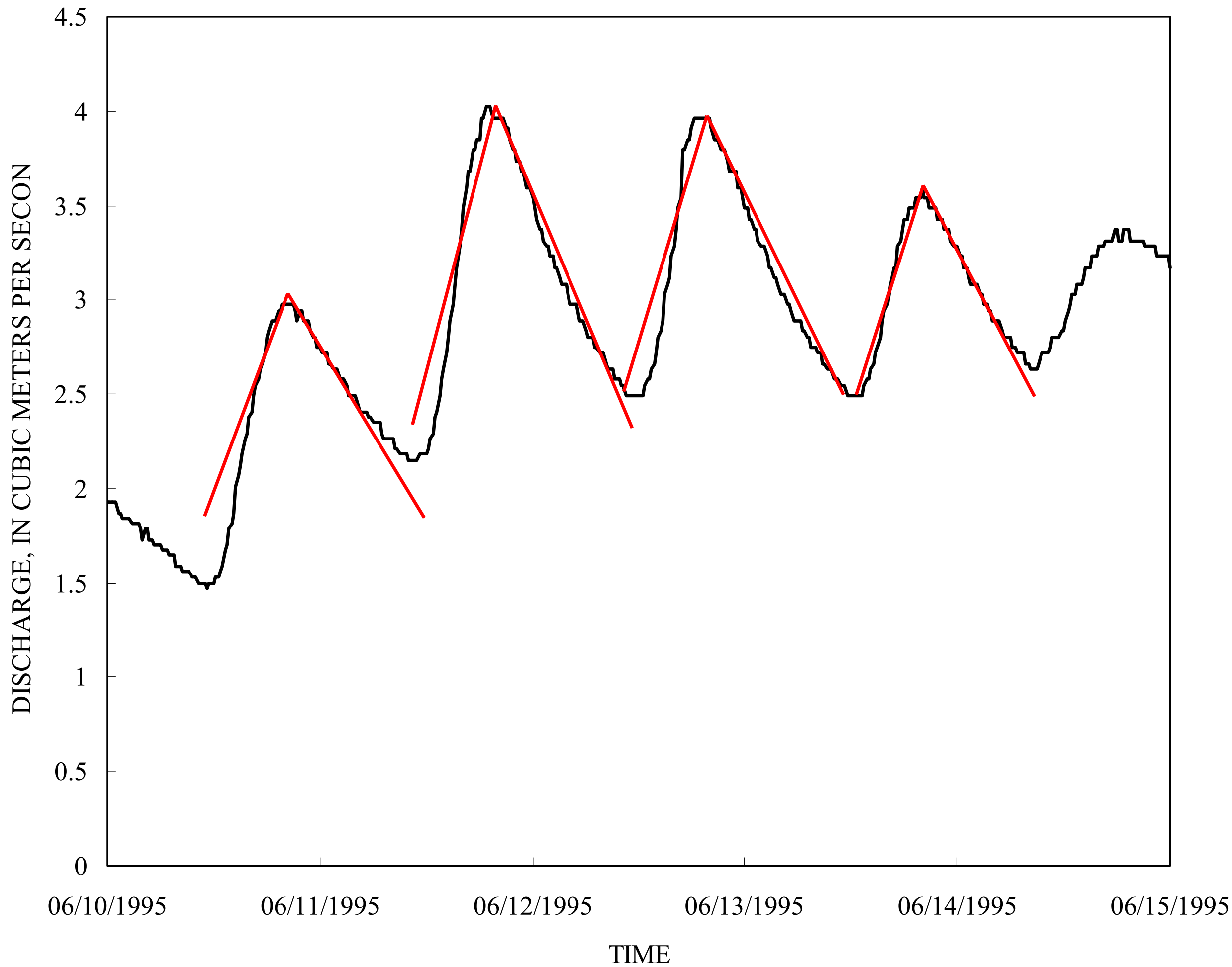

Figure 5-31. Hydrograph shape of typical snowmelt runoff events. NRCS (1996) triangular hydrograph (red line) is superimposed on the measured discharge record. Discharge data is from USGS gaging station 10336674 on Ward Creek.

Ward Creek

Modeling Reach. The modeling reach of Ward Creek extends from the mouth of the channel (river km 0.09) to river km 5.80 (Figure 5-30). The water and sediment loadings into the modeling reach are provided by the watershed model AnnAGNPS. The modeling reach is composed of 17 cross sections (Figure 5-30). These cross sections are hereafter referred to as cross sections "1" through "17," where "1" is the most upstream cross section and "17" is the most downstream cross section. These cross sections were surveyed during the data collection campaign in the fall of 2002 (see section 2.2).

Physical Properties. Roughness values were assigned to bed, bank, and floodplain sections of each cross section based on visual inspection of the channel and following guidelines set forth by Aldridge and Garrett (1973) and Jarrett (1985). Bed- and bank-material composition and properties at each cross section were provided by local sediment samples and BST tests (section 2.3). Ward Creek streambanks, on average, have the highest measured silt/clay content of those streams sampled, 17%. In case these data were locally unavailable, data collected at the nearest similar site were used. Table G-3 in the appendix lists the data used at each cross section.

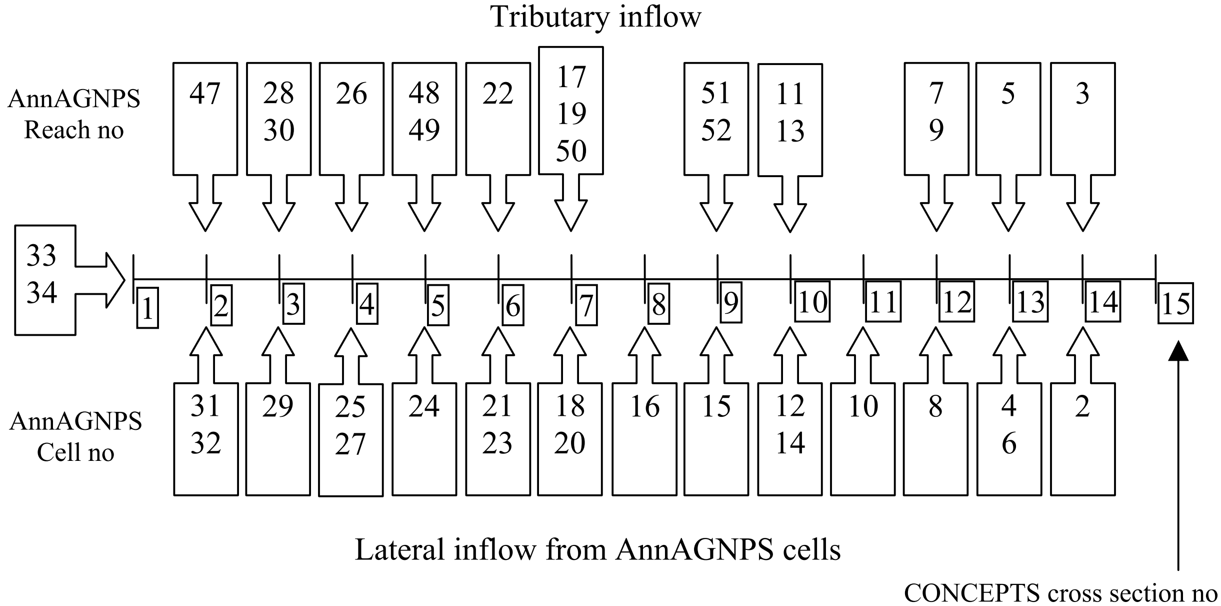

Figure 5-32. Linkage between AnnAGNPS reaches and cells (Figure 5-8) and CONCEPTS cross sections for General Creek. (The last digit of the cell ID (a 2 or a 3) is omitted.)

5.3.2 Tributary and Lateral Inflow

AnnAGNPS provides peak flow discharge (m^3/s), runoff volume (m^3), and clay, silt, and sand mass (T) for each runoff event for reaches and cells draining into the modeling reach. These data are then converted into triangular-shaped hydrographs (NRCS, 1986). The duration of the hydrograph is calculated as twice the runoff volume in m^3 divided by the peak discharge. The time-to-peak occurs at 37.5% of the hydrograph duration. The shape of the hydrograph and the value of time-to-peak agree well with that observed for snowmelt events in the Lake Tahoe basin (Figure 5-31).

The linkage between AnnAGNPS cells and reaches and CONCEPTS cross sections is shown in Figure 5-32 for the modeling reach along General Creek, Figure 5-33 for the Upper Truckee River, and Figure 5-34 for Ward Creek. The AnnAGNPS reach and cell IDs in these figures are those of AnnAGNPS subareas. The subarea ID can be obtained from the reach or cell ID by omitting the last digit of the latter ID (a 1, 2, 3, or 4). The reach and cell IDs for General Creek, Upper Truckee River, and Ward Creek are shown in Figures 5-8, 5-14, and 5-18, respectively.

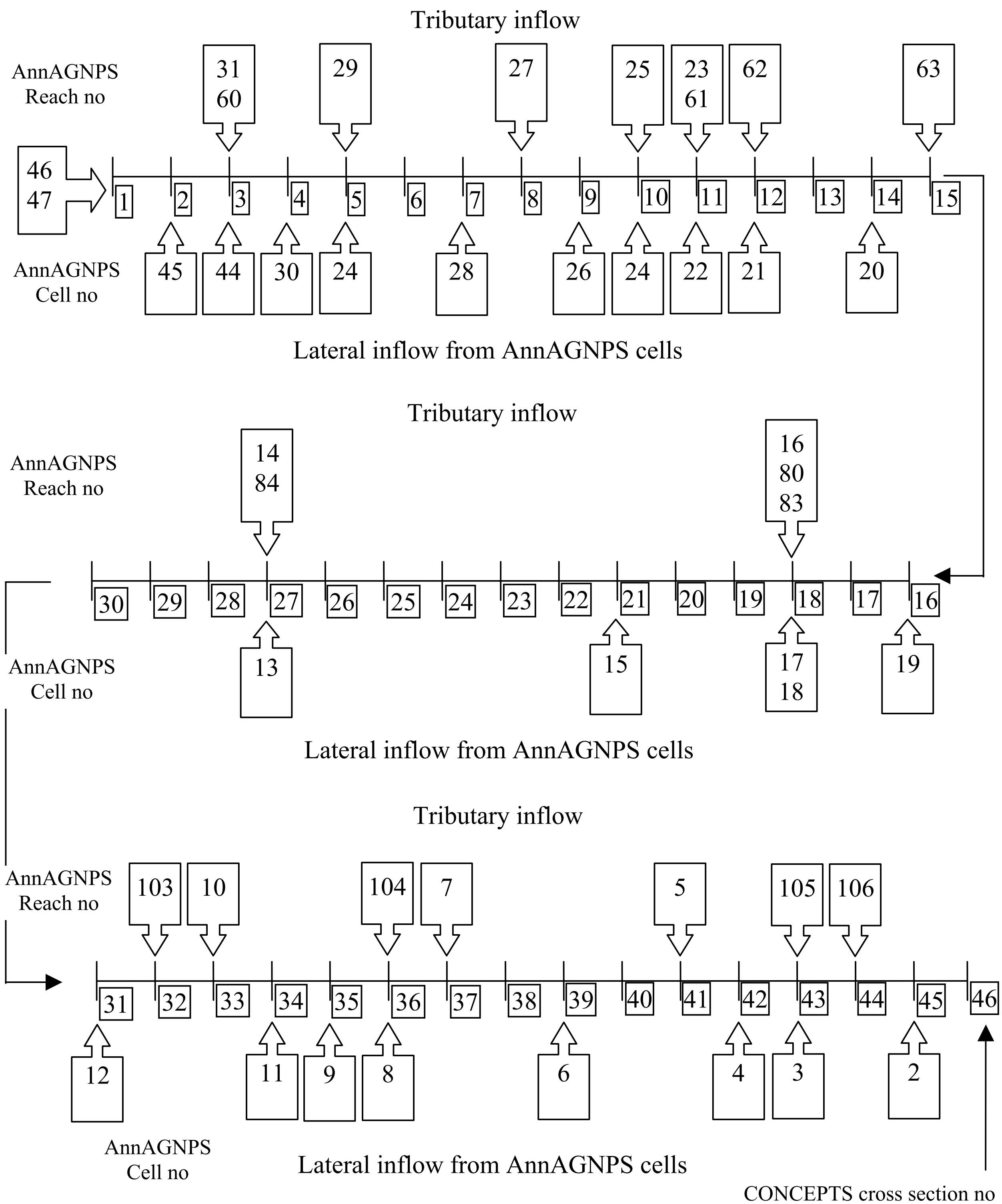

Figure 5-33. Linkage between AnnAGNPS reaches and cells (Figure 5-14) and CONCEPTS cross sections for the Upper Truckee River. (The last digit of the cell ID (a 2 or a 3) is omitted.)

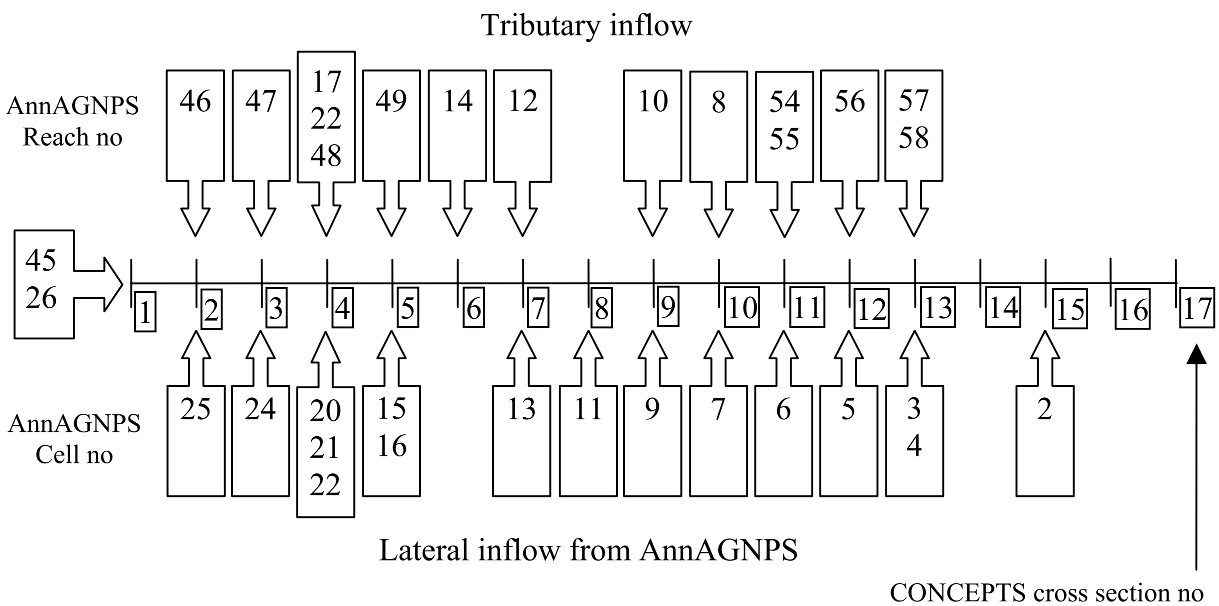

Figure 5-34. Linkage between AnnAGNPS reaches and cells (Figure 5-18) and CONCEPTS cross-sections for Ward Creek. (The last digit of the cell ID (a 2 or a 3) is omitted.)

5.4 <u>Model Validation and 50-Year Simulation</u>

5.4.1 General Creek

AnnAGNPS

Since AnnAGNPS provides the loadings into the main channel for eventual simulation by CONCEPTS, an evaluation of the capability of AnnAGNPS to reproduce the measured values of runoff, sediment, and peak rates helps in developing the input parameters needed by CONCEPTS in reproducing trends in watershed loadings. The location of an USGS gaging station (10336645) near the outlet of the watershed provided data needed for this comparison as well as any calibration that would be required. While AnnAGNPS can produce information at any point in the watershed, this gage was the only point available to compare simulated results with measured data. There were several techniques used to evaluate the performance of AnnAGNPS on the General Creek watershed by comparing annual and monthly runoff and sediment as well as an evaluation of the sources of the runoff and sediment within the watershed.

<u>Annual Runoff</u>. The annual runoff was simulated from 1976 to 2002 at station 10336645, while measured runoff was only available from 1981 to 2000 (Figure 5-35). The percentage of precipitation to runoff was very high, mainly because the snowmelt process occurred too early in the year. The comparison of measured and simulated runoff was good, but in some years the snowpack at higher elevations was not adequately reflected at the Tahoe City climate station resulting in underestimation of total runoff (Figures 5-35 and 5-36). Better climatic information would have improved the simulations of runoff.

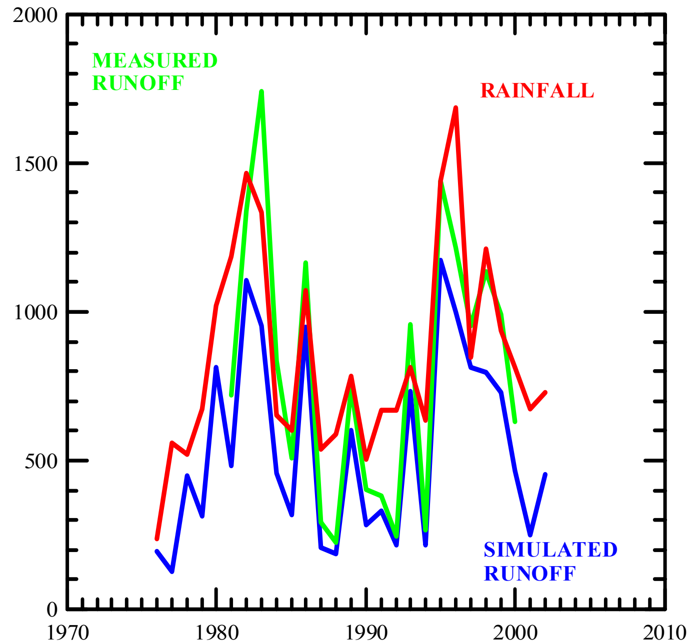

Figure 5-35. AnnAGNPS simulated and measured yearly runoff at the USGS gaging station 10336645 and the yearly precipitation from the Tahoe City climate station used within the simulation of the General Creek watershed.

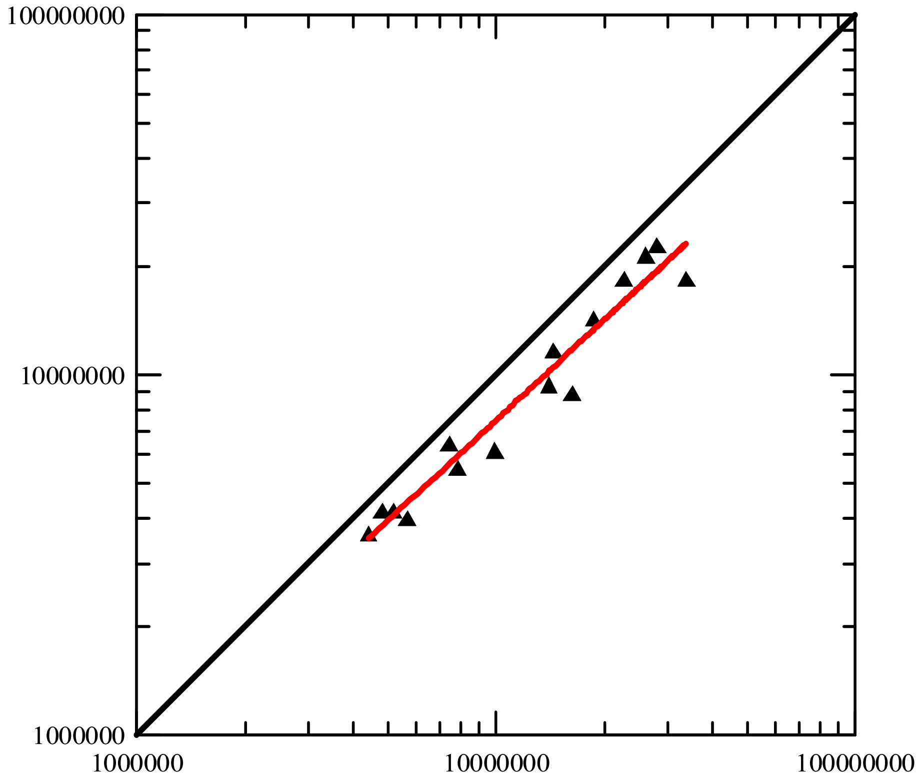

Figure 5-36. AnnAGNPS simulated versus measured yearly runoff from 1981-2000 at station 10336645, General Creek watershed.

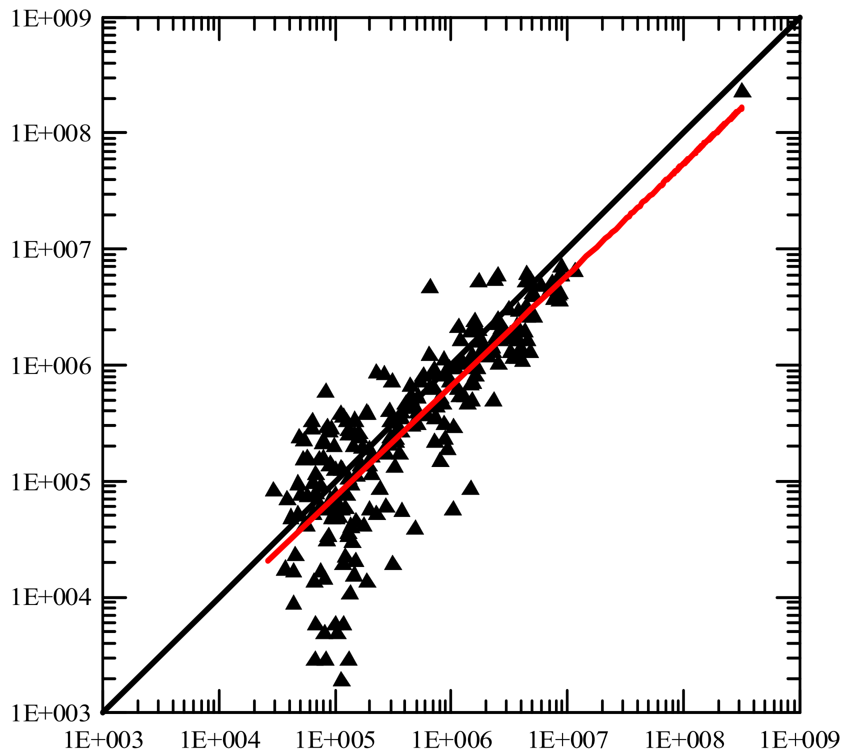

Figure 5-37. AnnAGNPS simulated versus measured monthly runoff during 1981-2000 at the station 10336645, General Creek watershed.

Monthly Runoff. Simulated monthly runoff was compared with measured data for all months from 1981 t -2000 at station 10336645 (Figure 5-37). The trend of simulated monthly runoff matched the measured data very well indicating that the modification made to the lapse rate (Figure 5-24) was appropriate for matching the timing of snowmelt peaks. Since precipitation occurred mainly as snowfall, it is critical that snowmelt be accurately reflected so that channel erosion could be adequately simulated by CONCEPTS.

Annual Fine-Sediment Loads. Simulated, annual fine-sediment loads were compared to calculated annual values at station 10336645 from 1981 to 2001 (Figure 5-38). Simulated fine-sediment transport compared relatively well with data from the gaging station in low- and moderate-flow years. For high flow and sediment- producing years such as 1983 and 1997 where AnnAGNPS results are low relative to the calculated values at the gage, the bulk of the sediment may be coming from channel sources. The application of CONCEPTS will show considerable improvement in the comparison with measured values.

Monthly Fine-Sediment Loads. Monthly, simulated fine-sediment loads were compared with data from station #0336645 for the period 1981 to 2001 (Figure 5-39). General temporal variability of the simulated fine-sediment loads matched the measured reasonably well indicating that upland sources of fine sediment may be an important contributor in the General Creek watershed. Fine-sediment loads simulated by AnnAGNPS from upland sources were less than the calculated values at the gage. This is to be expected because fine sediments emanating from channel sources are neglected here and will be simulated by CONCEPTS.

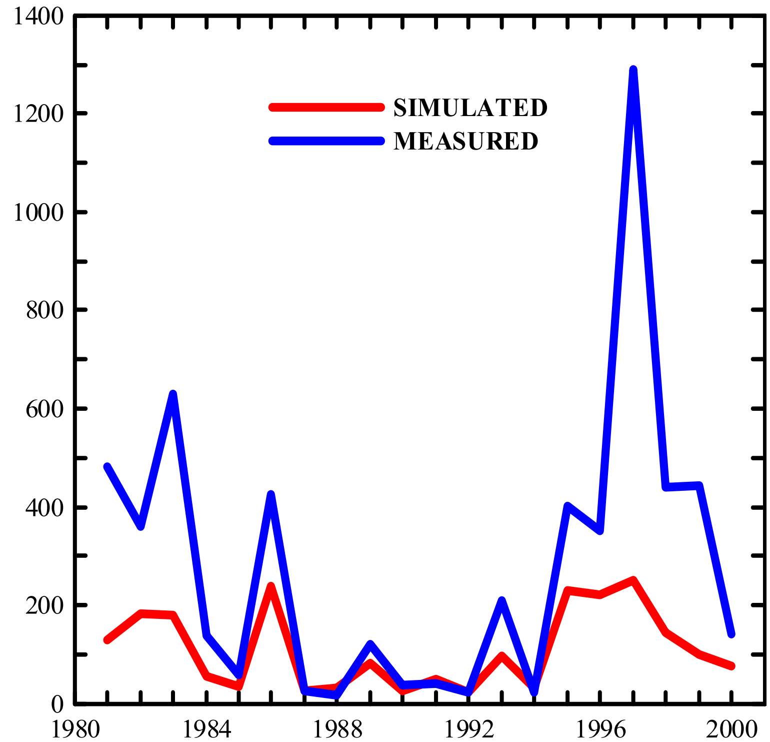

Figure 5-38. AnnAGNPS simulated and measured yearly sediment at station 10336645, General Creek watershed.

Sources. The simulated runoff by AnnAGNPS cells can be used to describe the degree of runoff from the various cells within the watershed (Figure 5-40). A significant amount of runoff occurs in the upper end of the watershed where the landuse is rock outcrop. The erosion that occurred within each AnnAGNPS cell can also show the spatial variability throughout the watershed (Figure 5-41). The fine sediment yield that reaches the edge of each AnnAGNPS cell also shows considerable variability throughout the watershed (Figure 5-42) For the most part, monthly fine-sediment loadings do plot around the line of perfect agreement in Figure 5-39, providing further evidence that upland sources may provide the majority of the fine sediment to the downstream gage.

Recurrence Interval for the Annual Maximum Instantaneous Peak Discharge. A comparison of measured and simulated peak discharges for water years 1981 – 2001 is shown in Table 5-5. Simulated peaks listed as CONCEPTS represent runoff values input from AnnAGNPS into CONCEPTS and then routed downstream by the channel-evolution model. Generally, the calculated annual peak discharge is 30 to 50 percent larger than those observed. The simulated peak discharge on January 2, 1997 is twice as large as that observed. The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 6.1, 11.7, 16.5, and 21.9 m^3/s, respectively. The corresponding peak discharges computed by: 1) AnnAGNPS are 8.0, 15.0, 21.8, and 30.5 m^3/s, respectively; and 2) CONCEPTS are 8.4, 15.9, 23.6, and 33.9 m^3/s, respectively.

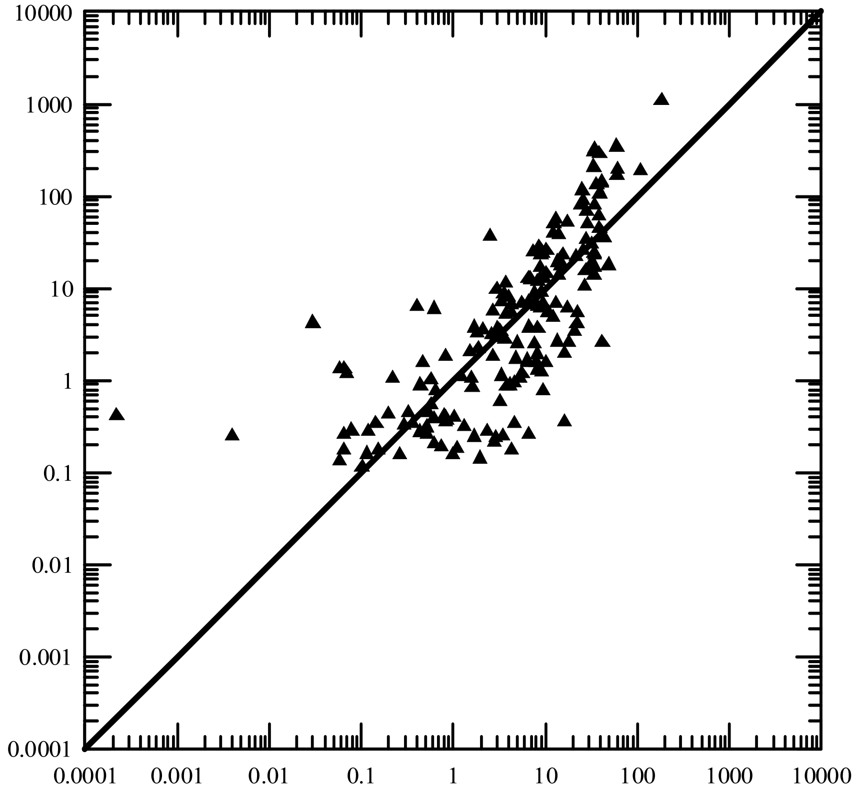

Figure 5-39. AnnAGNPS simulated versus measured monthly fine sediment during 1981-2000 at the USGS gaging station 10336645 at General Creek watershed.

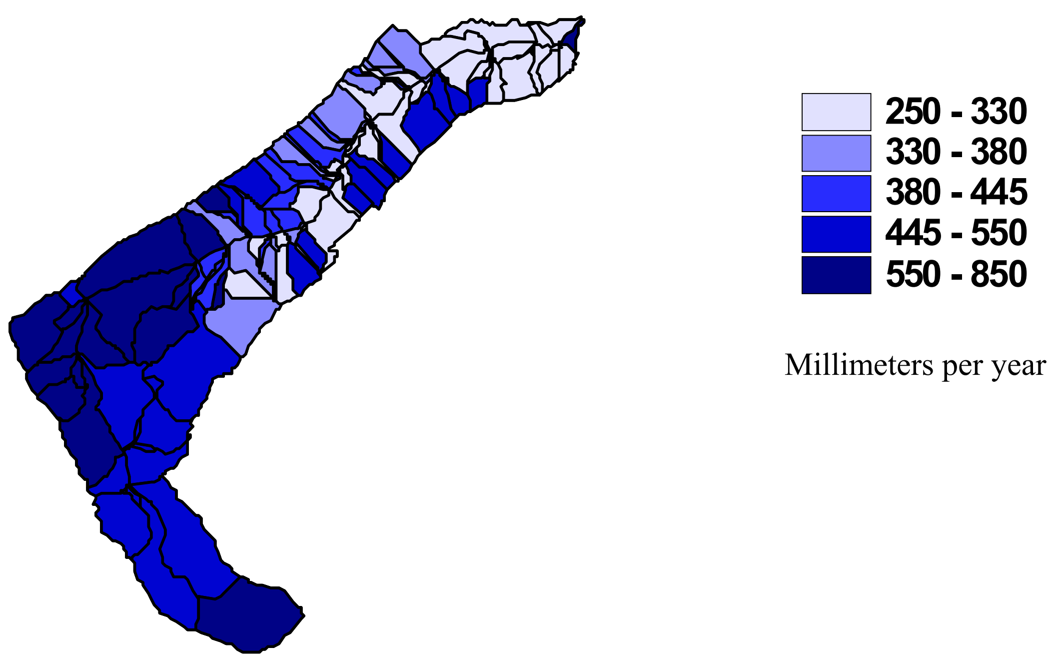

Figure 5-40. Average annual runoff simulated from AnnAGNPS for each cell on General Creek watershed.

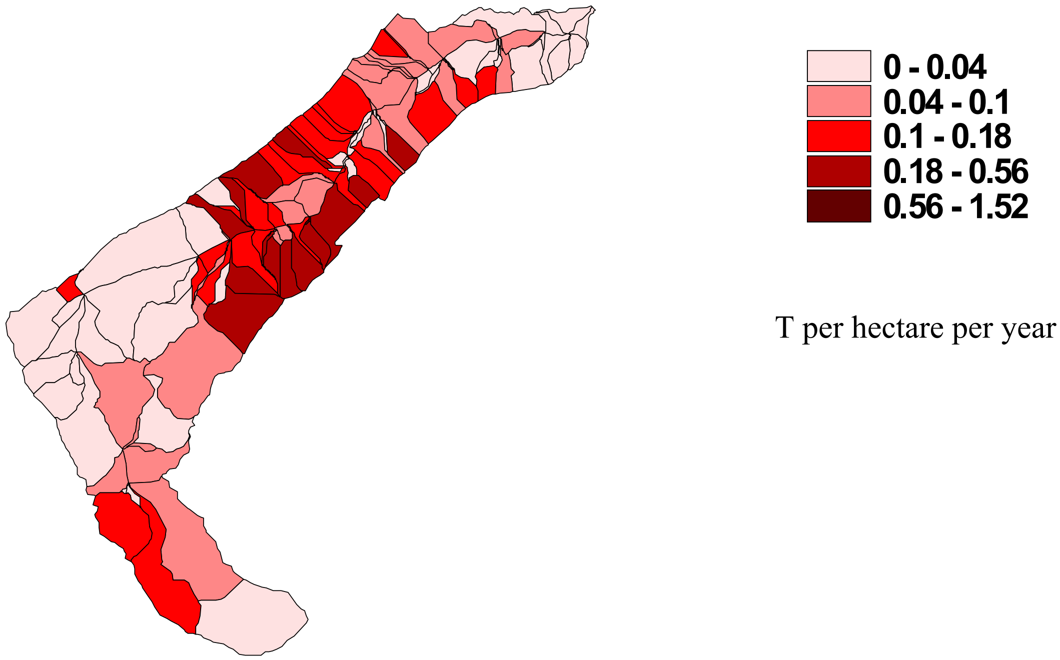

Figure 5-41. Average annual erosion simulated from AnnAGNPS for each cell on General Creek watershed.

Table 5-5. Comparison of measured and simulated annual peak discharge at USGS gaging station 10336645 on General Creek. Values are in cubic meters per second.

Water year	Observed	CONCEPTS	Water year	Observed	CONCEPTS
1981	3.79	5.73	1992	2.80	4.82
1982	21.66	25.45	1993	8.16	10.13
1983	9.49	9.10	1994	2.46	4.55
1984	10.17	8.43	1995	9.37	12.32
1985	3.65	4.66	1996	15.94	14.09
1986	15.12	28.80	1997	22.57	47.90
1987	2.92	5.26	1998	8.58	22.55
1988	1.22	3.46	1999	8.69	9.27
1989	5.69	8.07	2000	5.83	12.31
1990	2.46	4.58	2001	3.23	5.37
1991	4.36	6.55			

CONCEPTS Validation

Calculated suspended-sediment loads at station 10336645 (see section 3.4) and the observed changes at cross sections 2, 4, 6, and 13 between 1983 and 2002 were used to validate CONCEPTS for the period August 1983 through December 2002. Figures 5-43 through 5-46 show the results of the validation. Simulated annual peak discharges are listed in Table 5-5 and discussed above.

Changes in cross section geometry. Figure 5-43 shows that simulated cross-sectional changes between 1983 and 2002 agree very well with those observed. Changes in bed elevation along General Creek are negligible and channel width adjustment is minor. The simulated adjustment occurred in February 1986, whereas in reality it probably occurred during the high runoff events in the first week of January 1997 (see next subsection).

Sediment Load. Figure 5-44 compares measured and simulated monthly loads of fines (clay- and silt-sized particles), sands, and total suspended sediments. The points plot around the line of perfect agreement. The observed scatter is to be expected due to of the variability between measured and simulated monthly runoff (Figure 5-37). The r^2 values for the fines, sands, and total suspended sediments are 0.67, 0.43, and 0.70 respectively.

Generally, annual loads of fines, sands, and total suspended sediment appear to be correlated with variations in annual runoff (Figure 5-45). Years with low runoff correspond to years with low annual sediment loads. Increased measured load in 1997 is caused by streambank erosion, whose occurrence was simulated by CONCEPTS in 1986. The channel erosion has a similar effect on the measured and simulated magnitude of the annual load. The measured and simulated annual loads in the year in which channel adjustment occurred are approximately 1250 T. Between 1984 and 2001 measured average-annual sediment loads of fines, sands, and total suspended sediment are 61, 178, and 238 T, respectively. The corresponding simulated average annual loads are 64, 208, and 272 T, respectively. The simulated average annual load of fines (clays and silts) agrees well with that measured. The average annual load of sands is slightly overestimated.

Annually-averaged monthly sediment load of fines, sands, and total suspended sediment for each month is shown in Figure 5-26. Most sediment is transported during the snowmelt period from April through June. The simulated sediment loads agree quite well with those measured for this period. The high measured average sediment load for the month of January is caused by channel erosion during January 1997. The simulated erosion occurred in February 1996, increasing the simulated average sediment load for that month.

Of the total amount of fines delivered to the channel 78% is eroded from the uplands and 22% from the streambanks (Table 5-6). Streambanks contributed 60% of the sands and 53% of the total suspended sediment. Simulated total suspended-sediment loads averaged over the validation period are 241 T/y (41 T/y of fines), compared to 176 T/y calculated at station 10336645. Part of this discrepancy is due to the fact that CONCEPTS loads shown in Table 5-6 represents all sediment inputs along the modeled reach. In fact, some of this material is deposited on the bed during downstream transport.

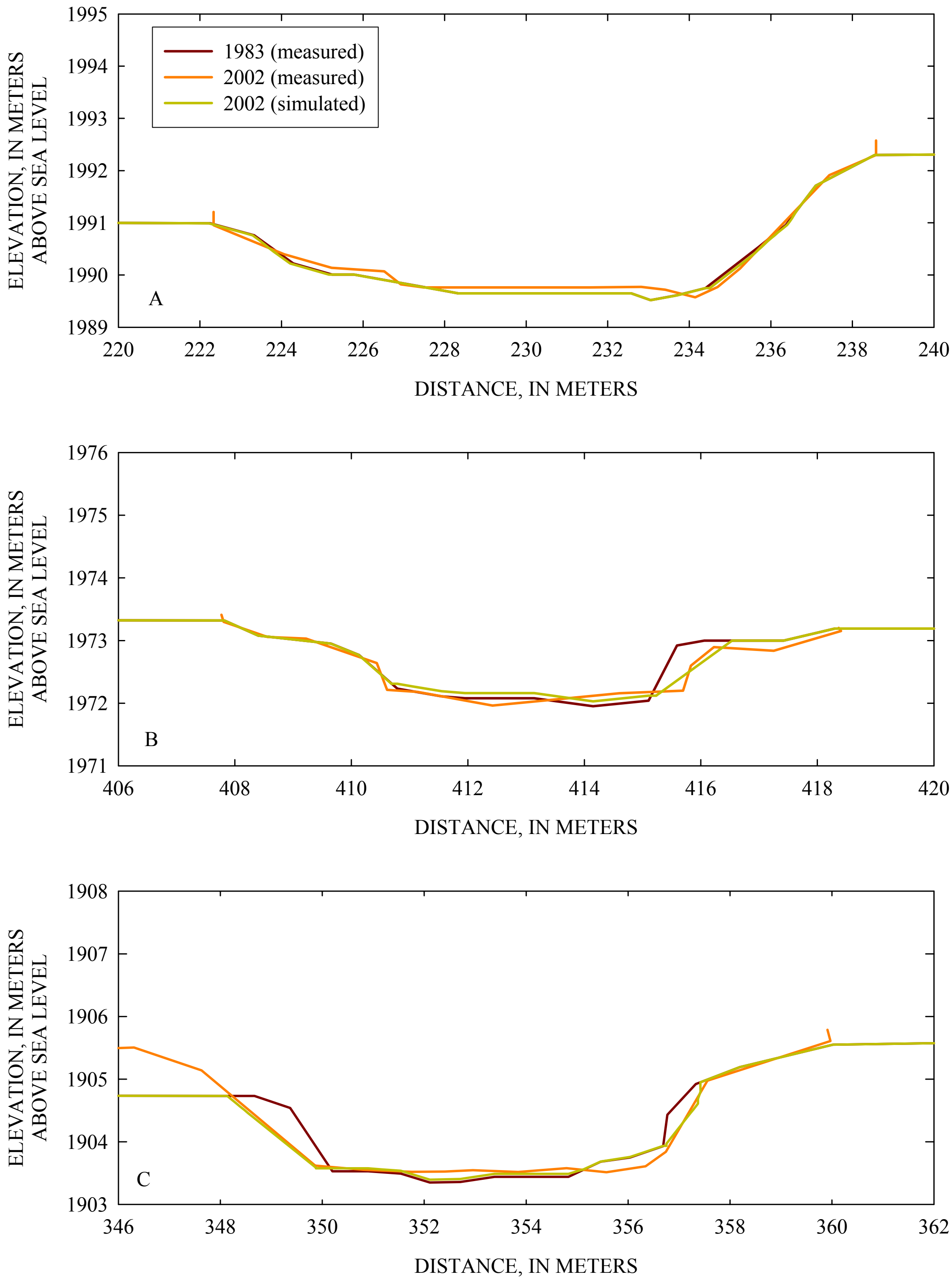

Figure 5-43. Comparison of observed and simulated cross-sectional changes at: A) CONCEPTS cross section 4 and NH60, B) CONCEPTS cross section 6 and NH70, and C) CONCEPTS cross section 13 and NH90.

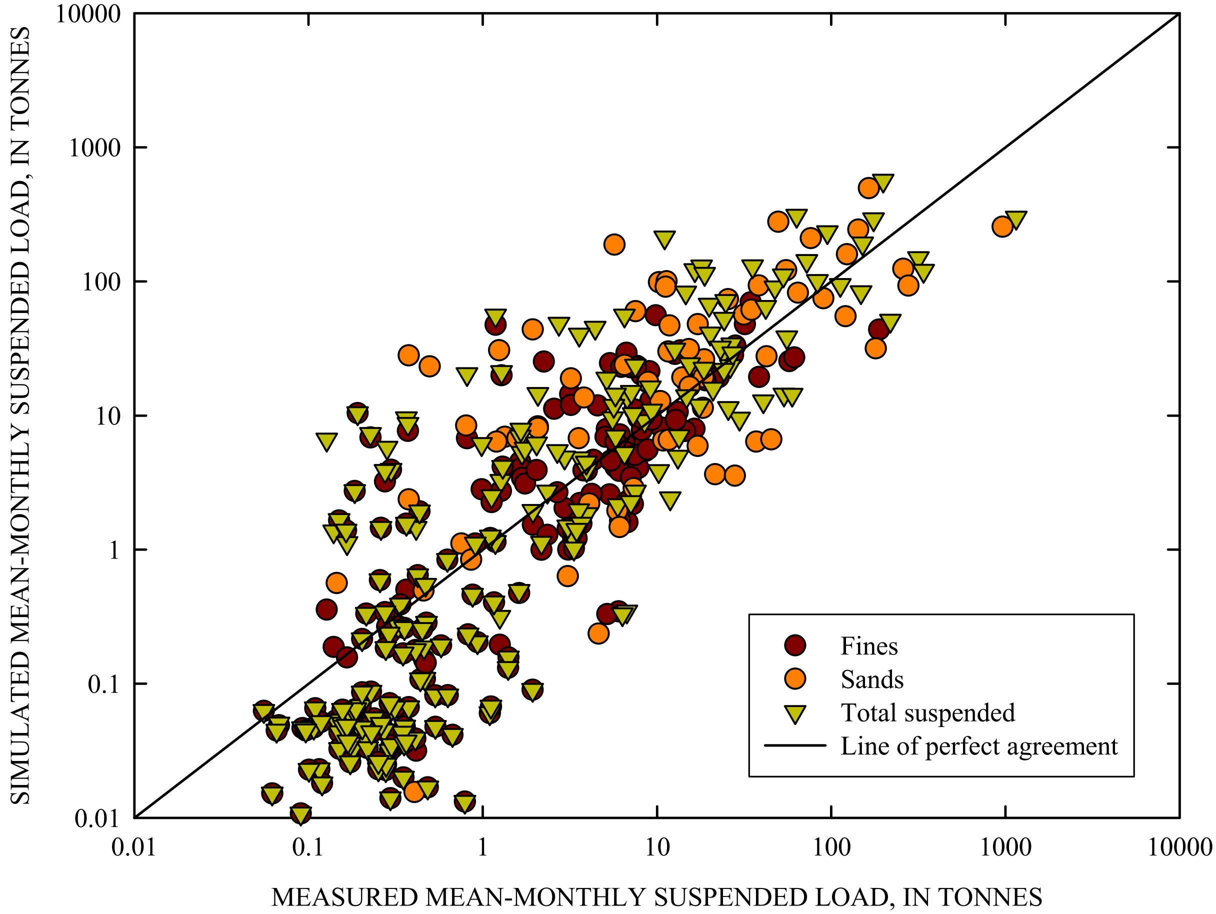

Figure 5-44. Comparison of measured and simulated monthly loads of fines (clay and silts), sands, and total suspended sediments at station 10336645, General Creek.

Table 5-6. Relative contributions of uplands and streambanks to suspended sediment load at the outlet of General Creek for the validation period.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	78	22	48
Sands	40	60	193
Total suspended	47	53	241

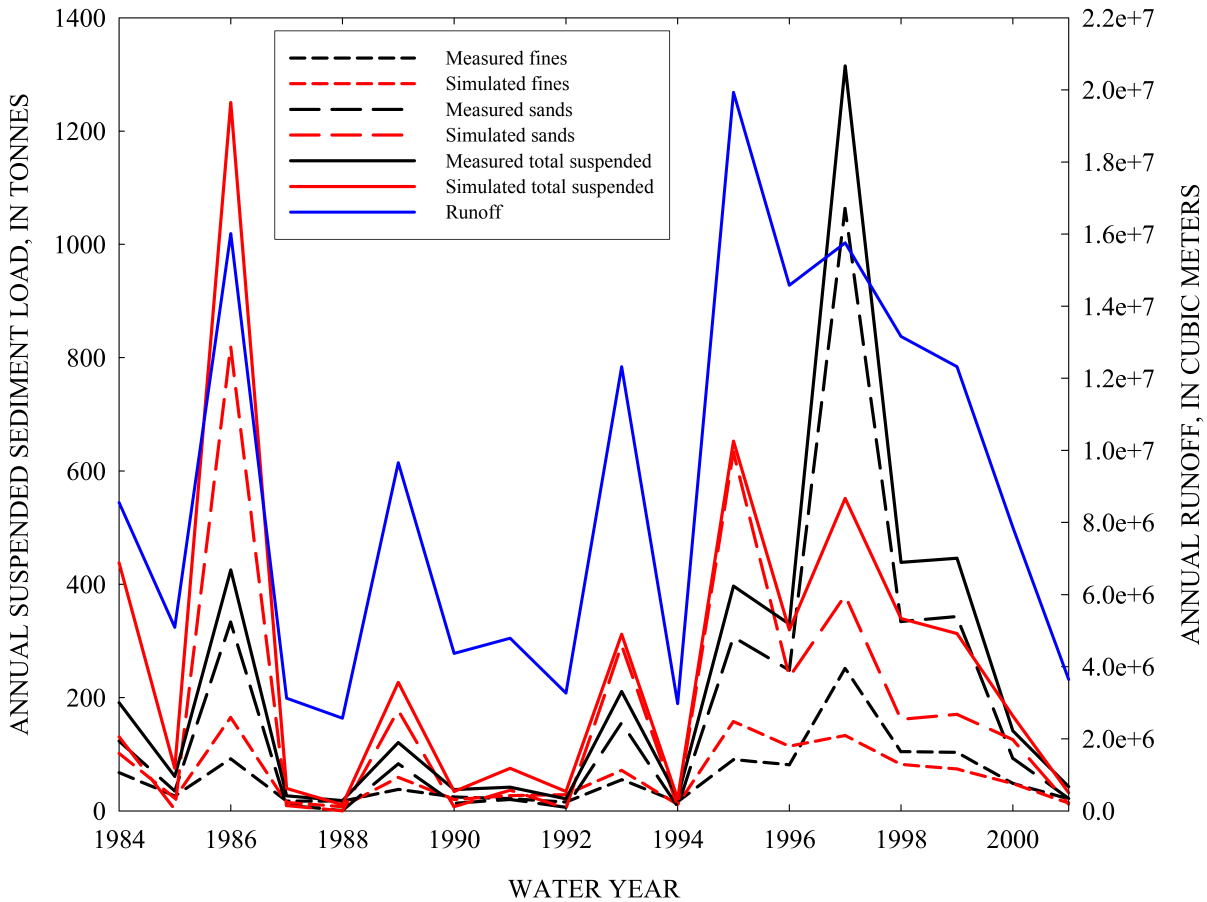

Figure 5-45. Comparison of measured and simulated annual loads at station 10336645, General Creek.

CONCEPTS 50-Year Simulation

A simulation with a 50-year flow record was performed to determine trends in sediment loads. Channel geometry is based on the 2002 cross-section surveys. All physical properties are those determined from the validation. The records of tributary and lateral inflow of water and sediments were constructed in the same way as the validation case. The runoff in years 28 through 50 is the same as in years 1 through 23 of the 50-year flow record, except the large storm event on January 2 of year 22 is not repeated in year 49.

Figure 5-47 shows changes in channel top width and bed elevation over the 50-year simulation period. Measurable changes in top width occurred at cross sections 2 (5 m) and 14 (2 m). Changes in thalweg elevation range from 0.05 m of erosion at cross section 9 to 0.12 m of deposition at cross section 14.

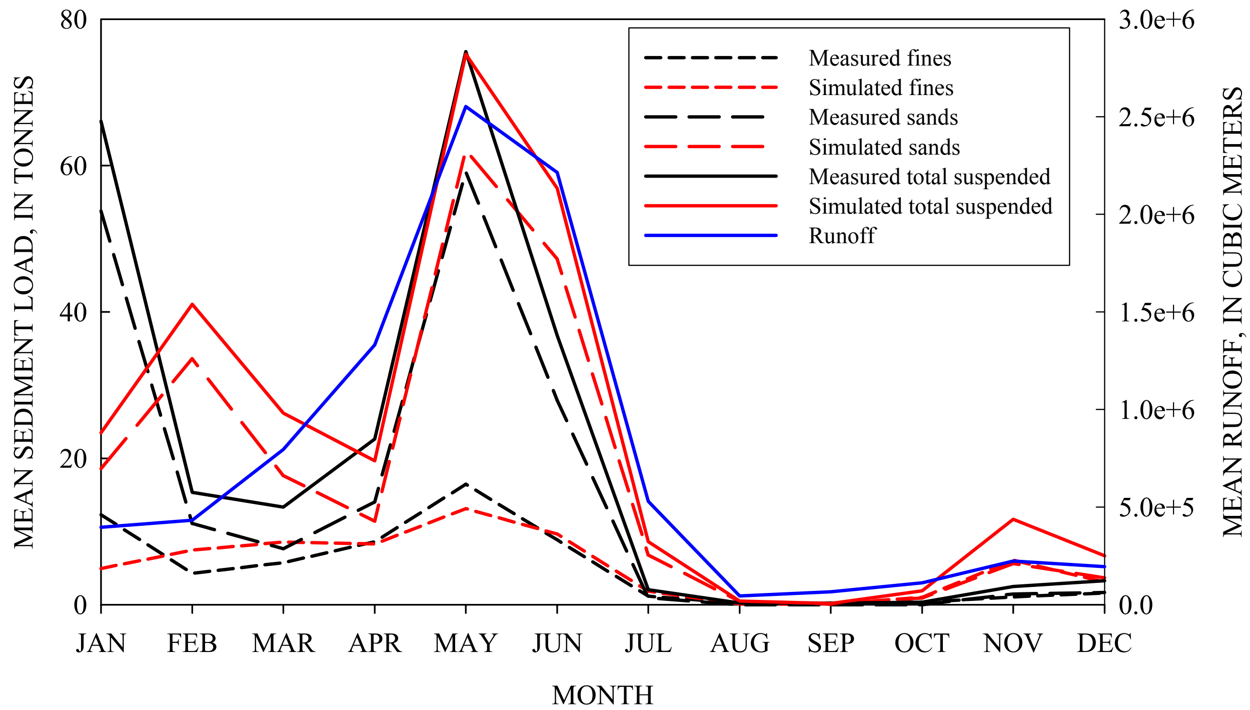

Figure 5-46. Comparison of measured and simulated annually-averaged monthly sediment loads and runoff at USGS gaging station 10336645 in General Creek.

Figure 5-48 shows the simulated annual runoff, and annual loads of fines, sands, and total suspended sediments at the outlet of General Creek. The annual loads in years 1 through 27 are larger than those in years 28 through 50 though annual runoff is the same. However, the annual load in year 38 is slightly larger than the corresponding load in year 11 because of an increase in sands transport. Channel adjustments over the first 27 years have led to a fairly stable-channel configuration, hence reducing the amount of sediments eroded from the channel. Thus, the 1997 runoff event does not seem to have rejuvenated the General Creek channel.

Over the 50-year simulation period, 72% of the total amount of fines delivered to the channel eroded from the uplands and 28% from streambanks (Table 5-7). Streambanks contributed 59% of the sands and 51% of the total suspended sediment.

Table 5-7. Relative contributions of uplands and streambanks to suspended-sediment load at the outlet of General Creek over the 50-year simulation period.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	72	28	51
Sands	41	59	144
Total suspended	49	51	196

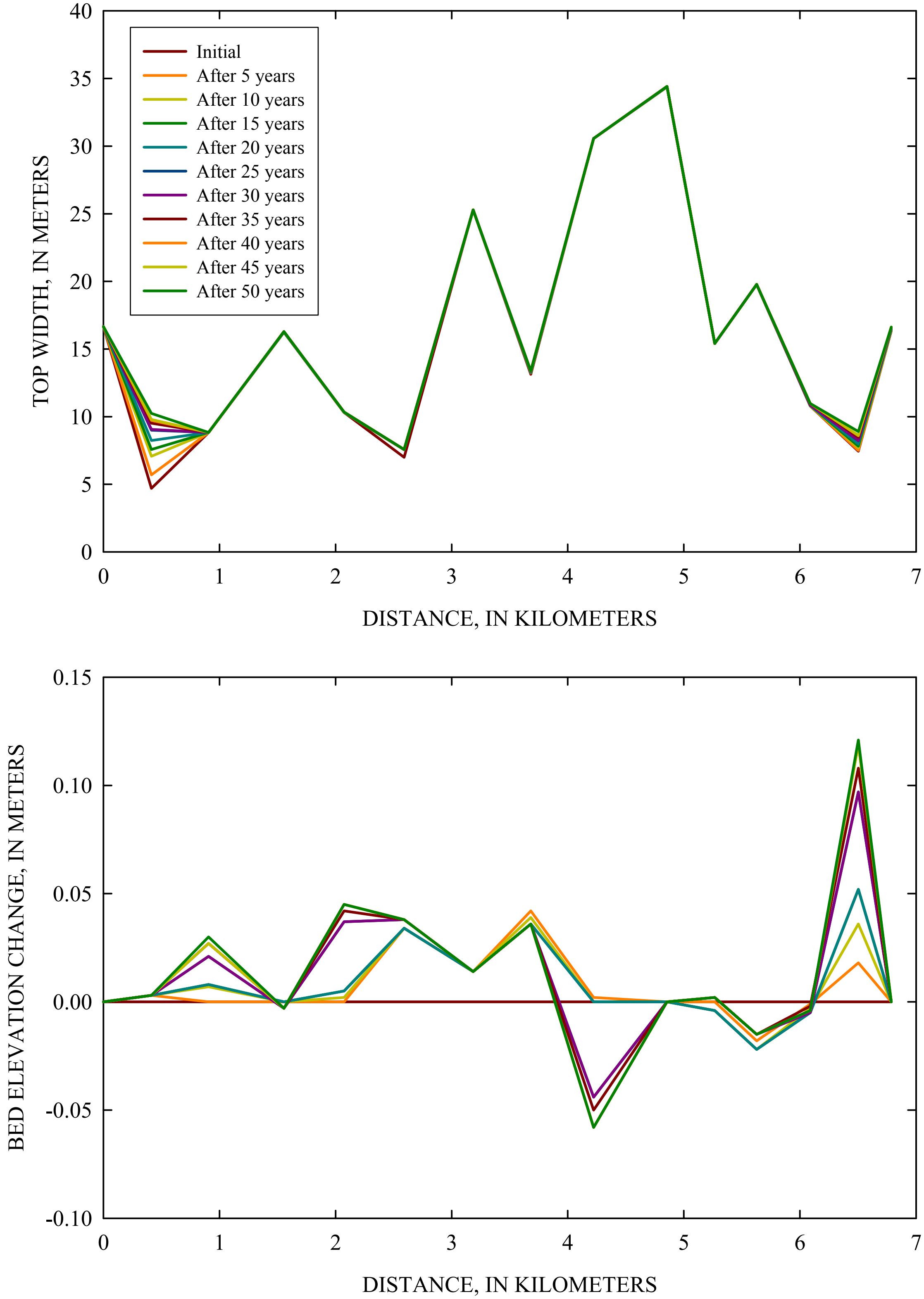

Figure 5-47. Simulated changes in top width and bed elevation along General Creek over a 50-year period.

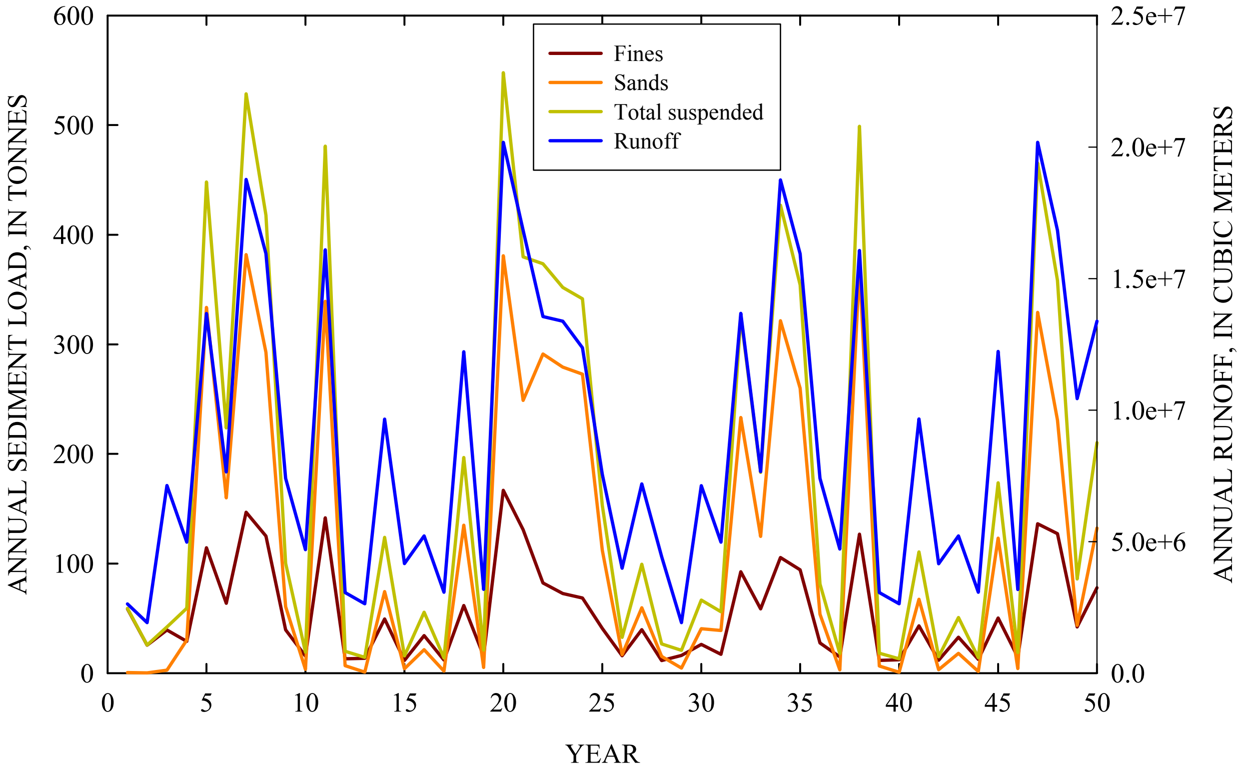

Figure 5-48. Simulated annual runoff and loads of fines, sands, and total suspended sediments at the outlet of General Creek for the 50-year simulation.

5.4.2 Upper Truckee River

AnnAGNPS

Three USGS gaging stations (10336610 at the lower end, 103366092 in the middle, and 10336580 at the upper end) were used to validate AnnAGNPS runoff simulations within the Upper Truckee River watershed. The diversion of water from Echo Lake out of the watershed required that those areas not be included in the AnnAGNPS simulation and thus were not be routed to the outlet.

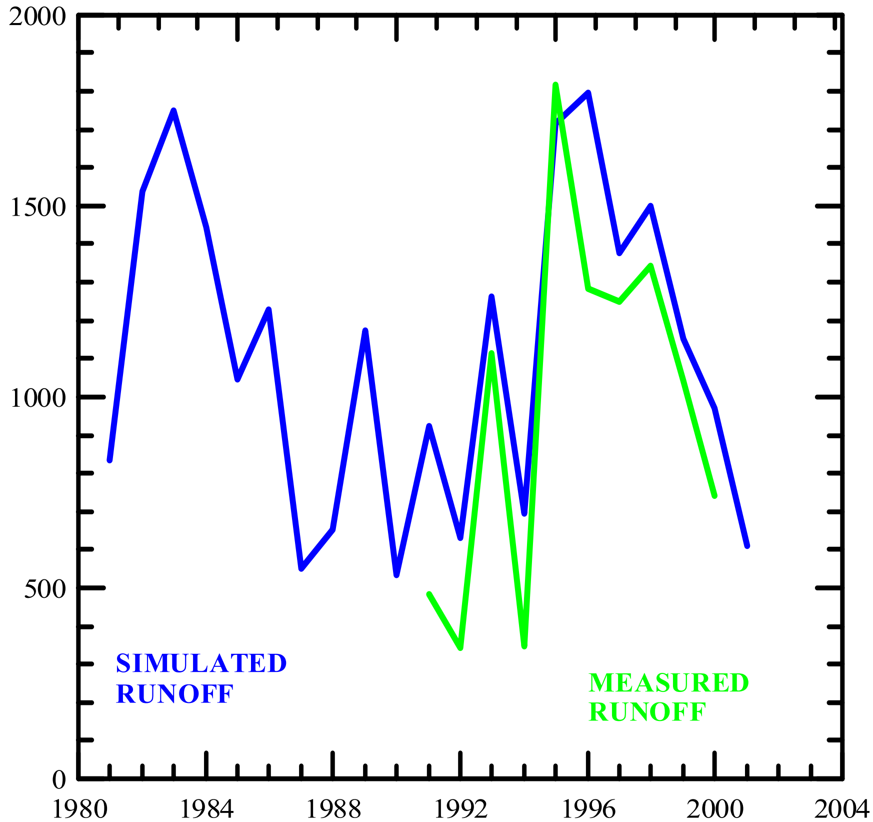

Figure 5-49. AnnAGNPS simulated and measured annual runoff at the upstream station (10336580) of the Upper Truckee River watershed.

Annual Runoff. Simulated annual runoff was determined from 1981 to 2001 at station 10336580, while measured runoff was available from 1991 to 2000 (Figure 5-49). The same years were available for station 103366092 (Figure 5-50). The simulated yearly runoff was determined from 1981 to 2001 at the USGS gaging station #10336610, while measured runoff was available from 1981 to 2000 (Figure 5-51). As with General Creek, simulated annual runoff results compare very well with those measured.

Monthly Runoff. Simulated runoff was compared with measured data from 1991-2000 at the upstream station (10336580; Figure 5-52), mid-reach station (103366092; Figure 5-53), and the downstream station (10336610; Figure 5-54). Monthly runoff volumes were not simulated well (Figure 5-52), particularly during periods of low and moderate flows. We suspect that this is due to over estimation of flows during winter months, thereby leaving an insufficient snowpack for large snowmelt peaks during April through June. Improved climatic information would also improve the model simulations.

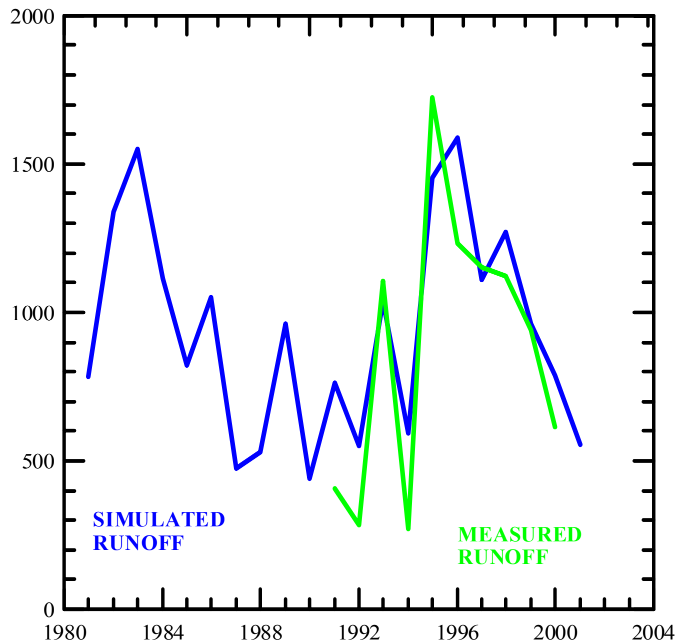

Figure 5-50. AnnAGNPS simulated and measured annual runoff at the mid-reach gaging station 103366092 of the Upper Truckee River watershed.

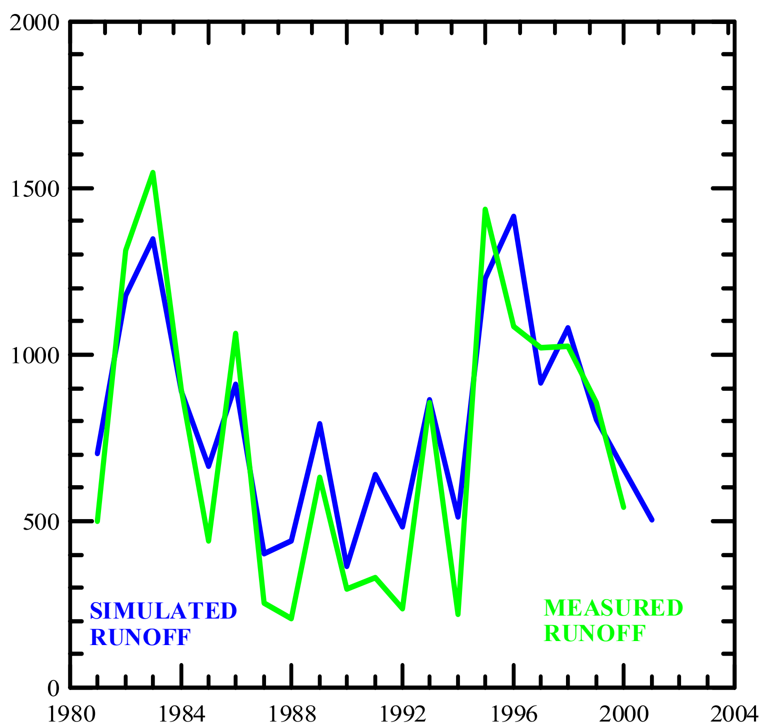

Figure 5-51. AnnAGNPS simulated and measured annual runoff at the downstream station 10336610 of the Upper Truckee River watershed.

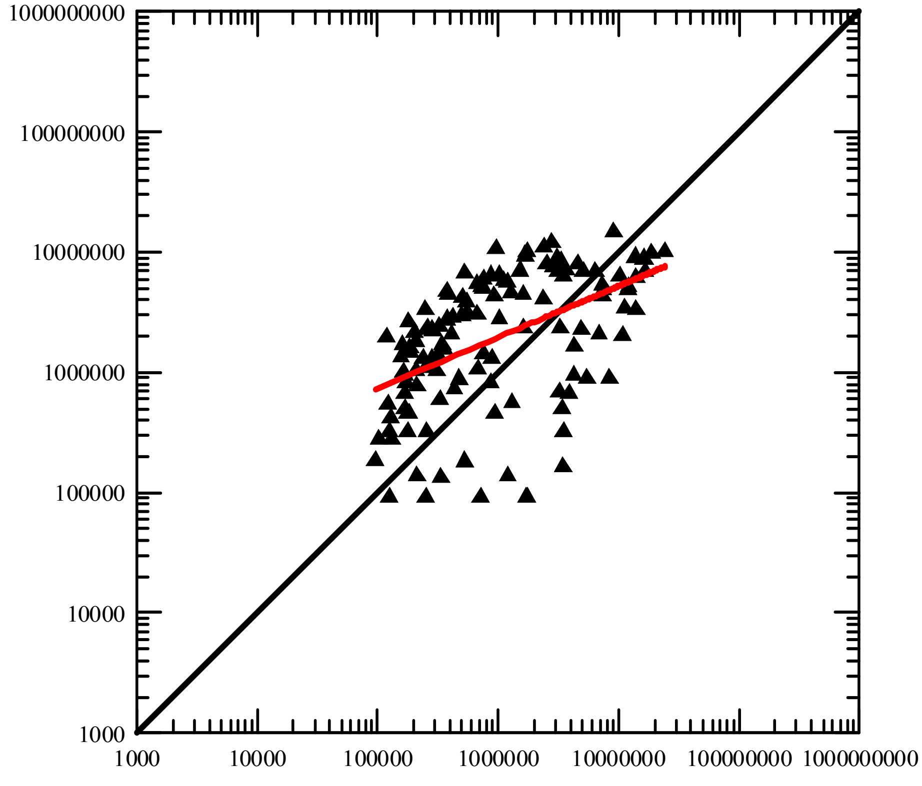

Figure 5-52. AnnAGNPS simulated versus measured monthly runoff during 1991-2000 at upstream station 10336580, Upper Truckee River watershed.

Annual Fine-Sediment Loads. Simulated annual fine-sediment loads were compared to measured data from the three gauging stations in the basin Figure 5-55 to 5-57. The comparisons show that at the upstream station (10336580) fine-sediment contributions from upland sources are proportionally high, relative to total suspended-sediment values measured at the station. With increasing distance downstream, the discrepancy between AnnAGNPS simulated loads and measured (calculated) loads increases due to greater contributions from channel sources that are not simulated by the upland model. These results agree with data on calculated suspended-sediment loads and yields discussed in sections 3.4 and 3.7.

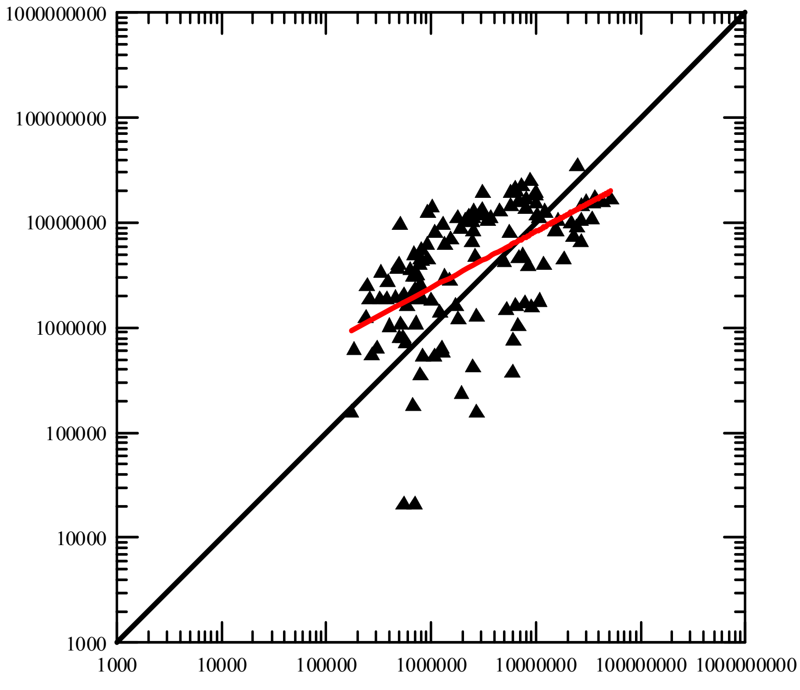

Figure 5-53. AnnAGNPS simulated versus measured monthly runoff during 1991-2000 at mid-reach station 103366092, Upper Truckee River watershed.

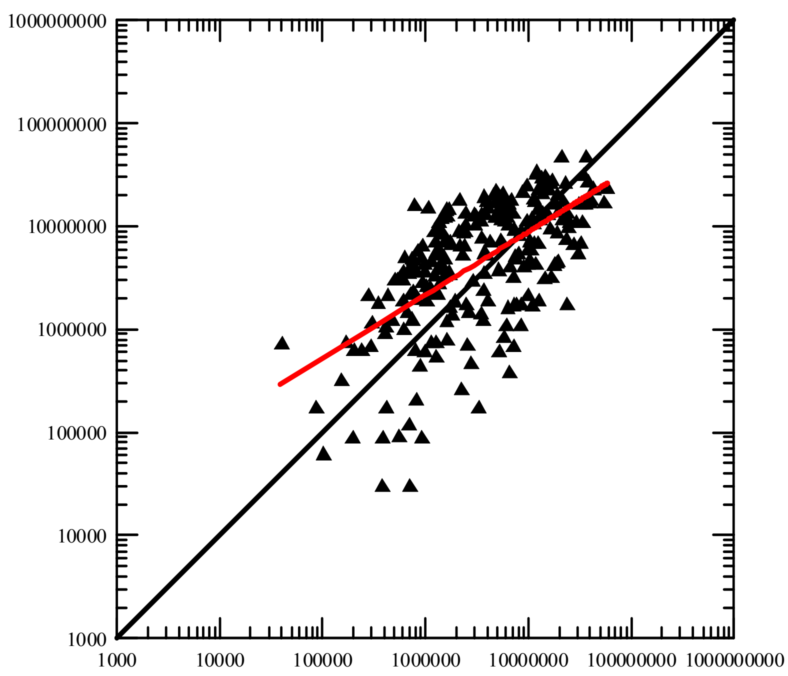

Figure 5-54. AnnAGNPS simulated versus measured monthly runoff during 1981-2000 at the downstream station 10336610, Upper Truckee River watershed.

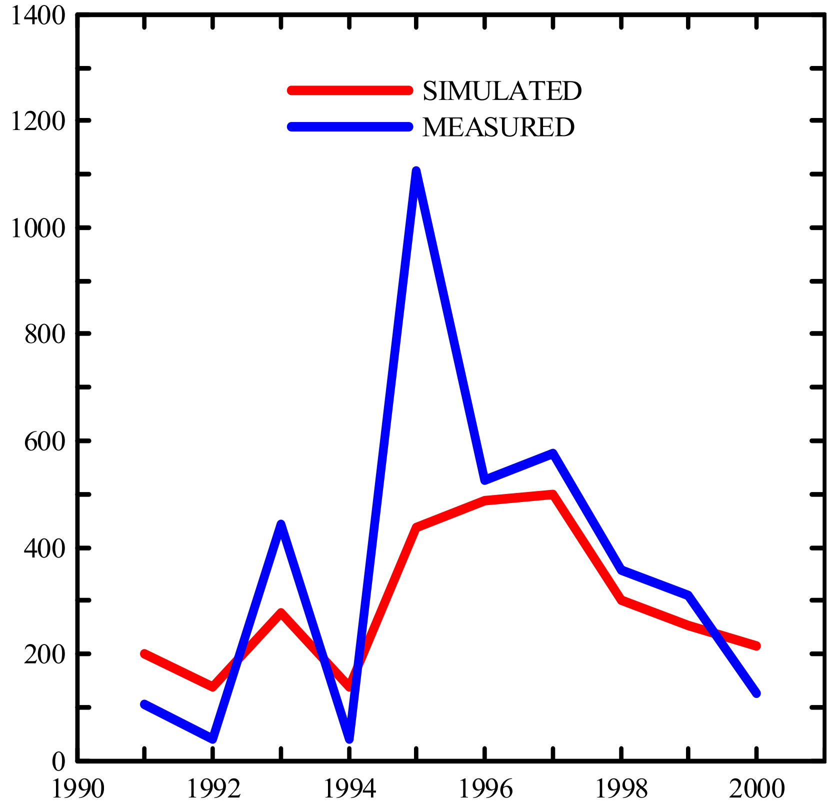

Figure 5-55. AnnAGNPS simulated and measured annual sediment loads at the upstream station 10336580, Upper Truckee River watershed.

Sources. A significant amount of runoff occurs in the upper end of the watershed where the land cover is rock outcrop (Figure 5-58). The fine sediment yield that reaches the edge of each AnnAGNPS cell also shows considerable variability throughout the watershed, but generally higher sediment yield values occur in the upper end of the watershed (Figures 5-59 and Figure 5-60).

Recurrence Interval for the Annual Maximum Instantaneous Peak Discharge. Tables 5-8 through 5-10 list the observed annual peak discharges at the USGS gaging stations 10336580, 103366092, and 10336610, respectively, and the annual (water year) peak discharges computed by AnnAGNPS routed to CONCEPTS. The simulated annual peak discharges are about 75 percent larger than those observed. The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 11.2, 21.4, 31.9, and 45.9 m^3/s, respectively.

At the mid-reach station (103366092) simulated annual-peak discharges agree better for the less frequent, large runoff events, but are still far too high for the more frequent, moderate runoff events. The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 23.9, 53.3, 84.3, and 125.5 m^3/s, respectively. The corresponding peak discharges computed by AnnAGNPS routed through CONCEPTS are 37.8, 70.8, 105.3, and 152.0 m^3/s, respectively.

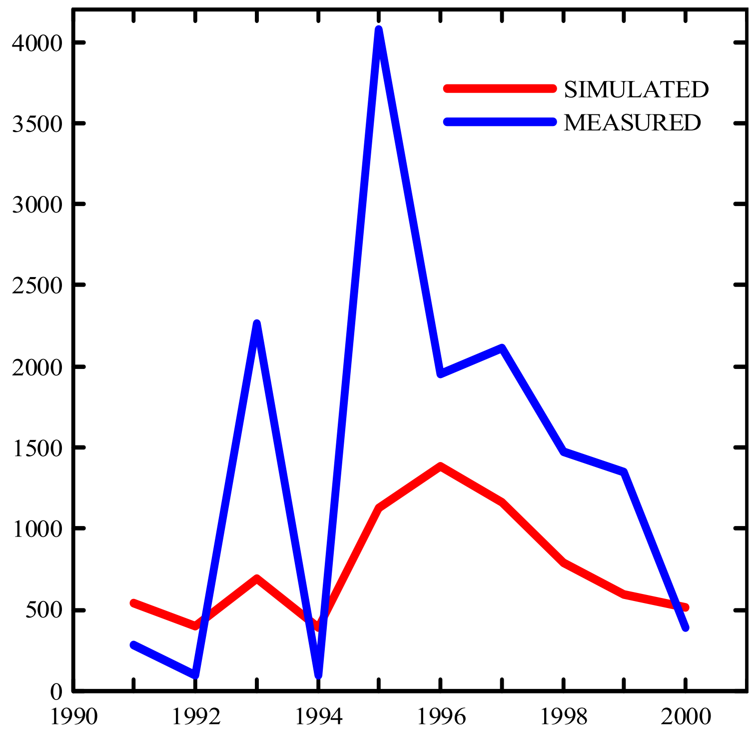

Figure 5-56. AnnAGNPS simulated and measured yearly sediment loads at the mid-reach station 103366092, Upper Truckee River watershed.

At the downstream, index station (10336610) the agreement between observed and simulated annual peak discharges worsens. The observed peak discharges reduce between stations 103366092 and 10336610, whereas the simulated peak discharges increase. The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 21.7, 48.7, 75.8, and 110.6 m^3/s, respectively. The corresponding peak discharges computed by: 1) AnnAGNPS routed through CONCEPTS are 52.8, 90.3, 124.5, and 166.1 m^3/s, respectively.

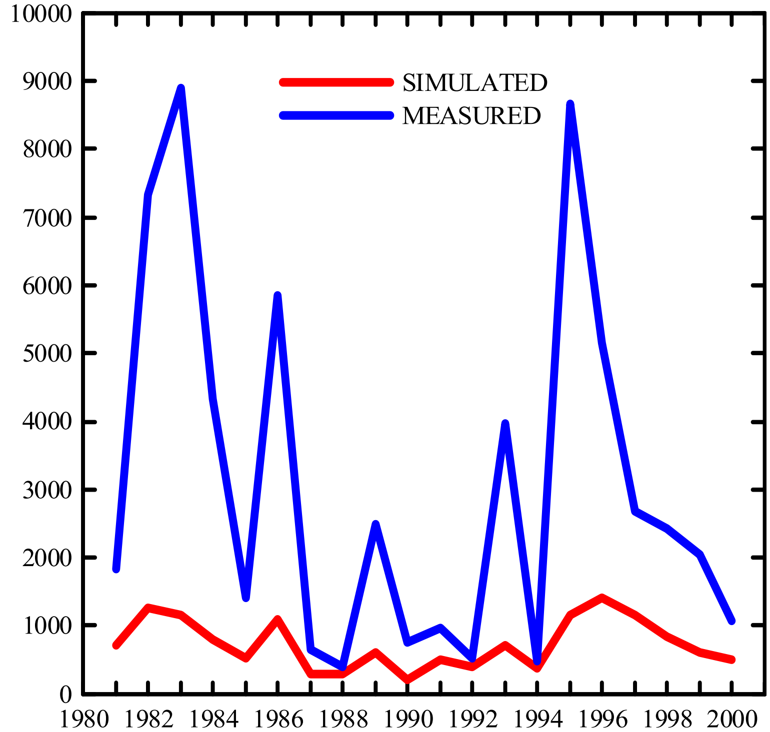

Figure 5-57. AnnAGNPS simulated and measured yearly sediment loads at the downstream station 10336610, Upper Truckee River watershed.

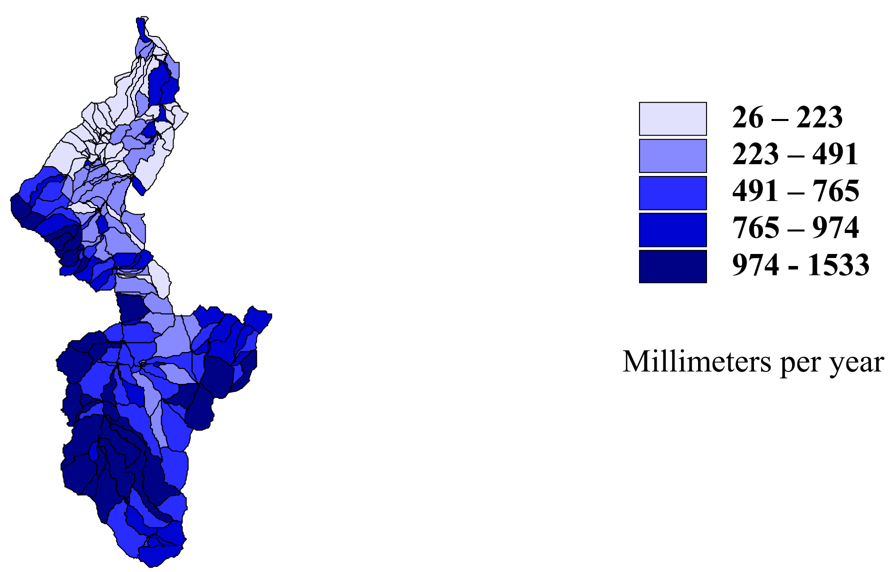

Figure 5-58. Average annual runoff simulated from AnnAGNPS for each cell on Upper Truckee River watershed.

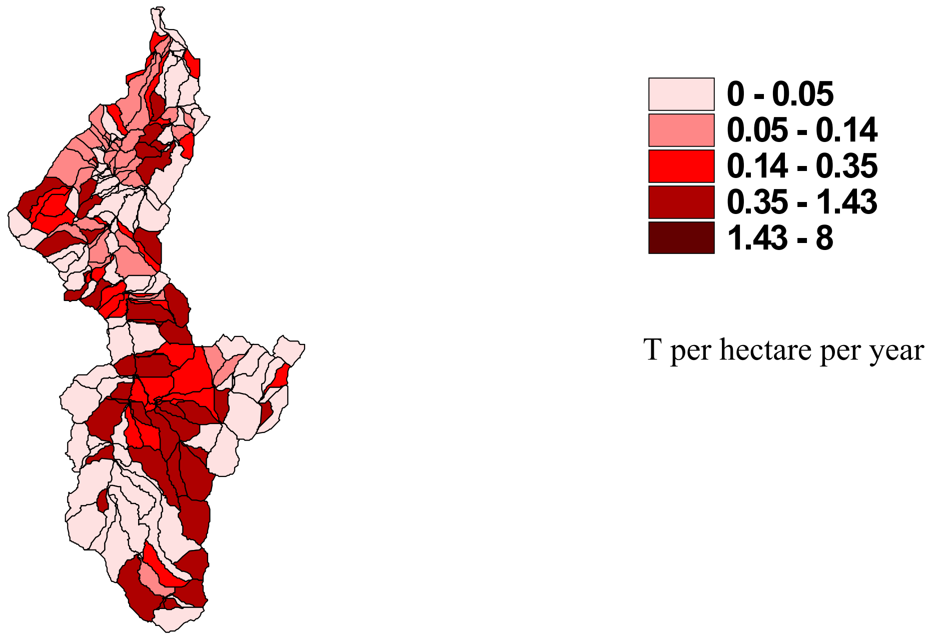

Figure 5-59. Average annual erosion simulated from AnnAGNPS for each cell on Upper Truckee River watershed.

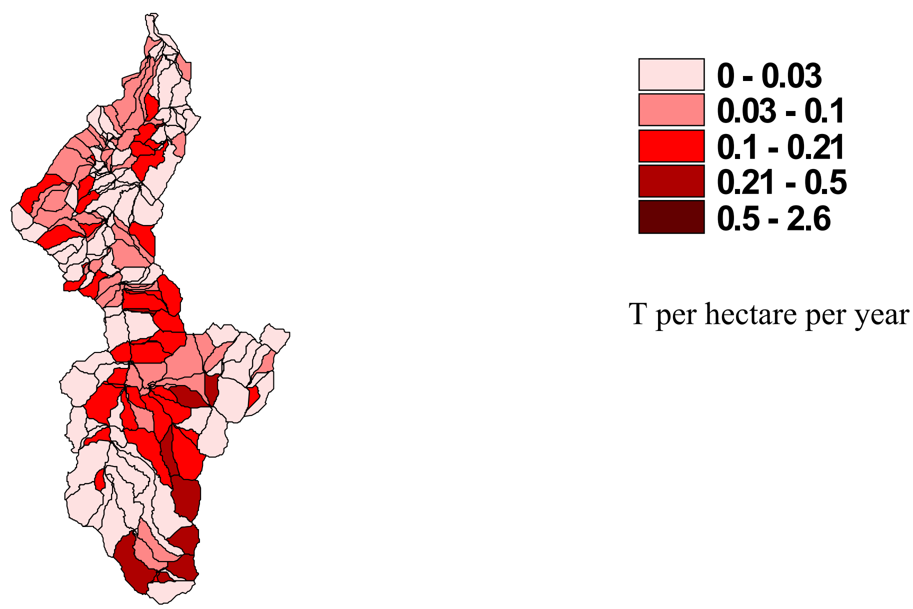

Figure 5-60. Average annual sediment yield simulated from AnnAGNPS for each cell on Upper Truckee River watershed.

Table 5-8. Comparison of measured and simulated annual peak discharge at USGS gaging station 10336580. Values are in cubic meters per second.

Water year	Observed	Water year	Observed
1991	8.72	1997	56.92
1992	4.59	1998	10.96
1993	13.20	1999	15.01
1994	5.75	2000	12.40
1995	15.55	2001	6.94
1996	26.76		

Table 5-9. Comparison of measured and simulated annual peak discharge at USGS gaging station 103366092. Values are in cubic meters per second.

Water year	Observed	CONCEPTS	Water year	Observed	CONCEPTS
1991	14.47	47.75	1997	144.98	182.47
1992	8.18	33.92	1998	24.15	43.78
1993	45.31	30.60	1999	34.83	27.81
1994	7.59	16.66	2000	23.50	28.06
1995	34.83	71.74	2001	9.97	22.31
1996	65.70	87.71			

Table 5-10. Comparison of measured and simulated annual peak discharge at USGS gaging station 10336610. Values are in cubic meters per second.

Water year	Observed	CONCEPTS	Water year	Observed	CONCEPTS
1981	9.97	51.15	1991	11.38	67.26
1982	72.21	125.41	1992	8.04	33.34
1983	36.81	55.01	1993	20.64	57.63
1984	39.08	69.80	1994	6.80	25.27
1985	13.00	42.44	1995	41.34	89.69
1986	77.59	150.53	1996	50.40	109.15
1987	15.09	28.23	1997	155.18	210.94
1988	4.81	23.14	1998	41.91	47.15
1989	16.85	51.50	1999	28.88	38.76
1990	6.68	36.17	2000	24.07	41.47

CONCEPTS Validation

Calculated suspended-sediment loads at stations 103366092 and 10336610 (see section 3.4) and the observed changes at cross sections 19 through 26 between 1992 and 2002 were used to validate CONCEPTS for the period from January 1981 through September 2001. Figures 5-61 through 5-64 show the results of the validation.

Changes in cross section geometry. In general, simulated changes in bed elevation along the Upper Truckee River are negligible, although there is 0.5 m of deposition at cross sections 24 and 44. Channel width adjustment is minor above river kilometer 18.There is approximately 1 m of widening between cross sections 12 and 15 and cross sections 38 and 44. Significant widening, up to 6 m, is simulated between cross sections 19 and 26. Figure 5-61 compares simulated cross-sectional changes at cross sections 19, 23, and 26 with those observed between 1992 and 2002. The simulated changes agree quite well with those observed. The simulated cross-sectional changes at cross sections 20, 21, 22, 24, and 25 (not plotted) compare fairly poorly with those observed. The channel segment containing these cross sections is highly sinuous. As a consequence, flow patterns are highly complex (three-dimensional) and cannot be captured by a one-dimensional flow model like CONCEPTS. For example, Figure 5-61C shows the flow-induced scour of the pool near the left bank of cross section 26.

Sediment Load. Figure 5-62 compares measured and simulated monthly loads of fines (clay- and silt-sized particles), sands, and total suspended sediments. The points plot around the line of perfect agreement. The observed scatter is to be expected in light of the variability between measured and simulated mean-monthly runoff (Figures 5-53 and 5-54). At station 103366092 the r^2 value for total suspended sediments is 0.40. At station 10336610 the r^2 values for the fines, sands, and total suspended sediments are respectively 0.45, 0.35, and 0.39.

Generally, annual loads appear to be correlated with annual runoff (Figure 5-63). Years with low runoff correspond to years with low annual sediment loads. The simulated annual load at gaging station 103366092 agrees quite well with that measured. However, the annual load in 1993 and 1995 is underpredicted. Figure 5-63A indicates that significant channel adjustments (bank widening) are simulated in 1997, because annual suspended-sediment load is relatively large. Between 1991 and 2001 the measured average annual total suspended-sediment load was 1287 T at station 103366092. The corresponding simulated average-annual load of total suspended sediment is 1251 T.

Between 1981 and 2001 the measured average annual fine, coarse, and total suspended sediment loads were 1258, 1700, and 2958 T/y, respectively at the downstream, index station 10336610. The corresponding simulated average annual loads are 1486, 2814, and 4300 T/y, respectively. The annual loads in 1986 and 1995 are underpredicted, whereas the annual loads for the low runoff years 1987 through 1992 are overpredicted (Figure 5-63B). It appears that too much sediment is transported at low discharges in the simulation. This discrepancy is mainly attributable to the high sand loads.

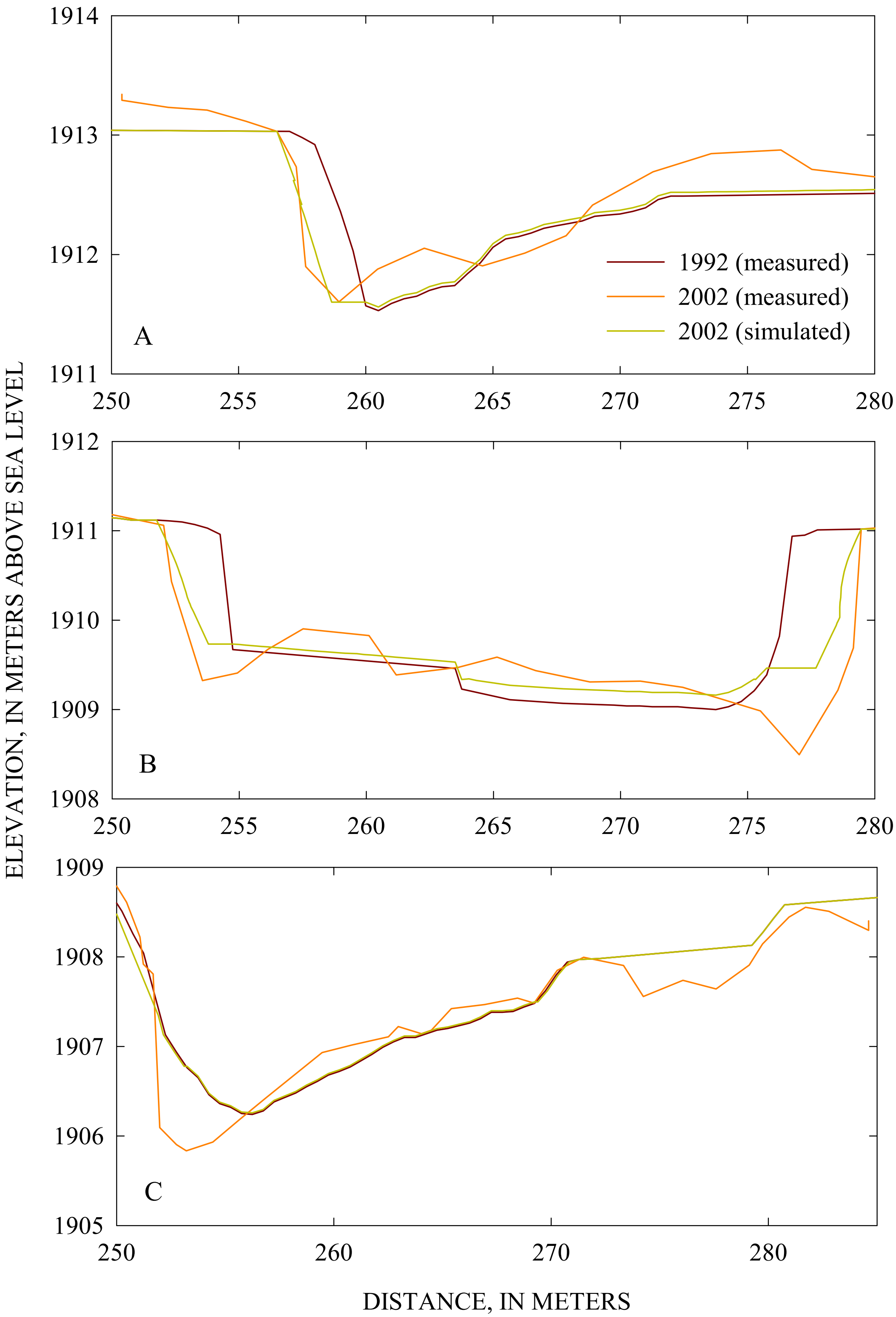

Figure 5-61. Comparison of observed and simulated cross-sectional changes at: A) CONCEPTS cross section 19 and 36, B) CONCEPTS cross section 23 and 50, and C) CONCEPTS cross section 26 and 61.

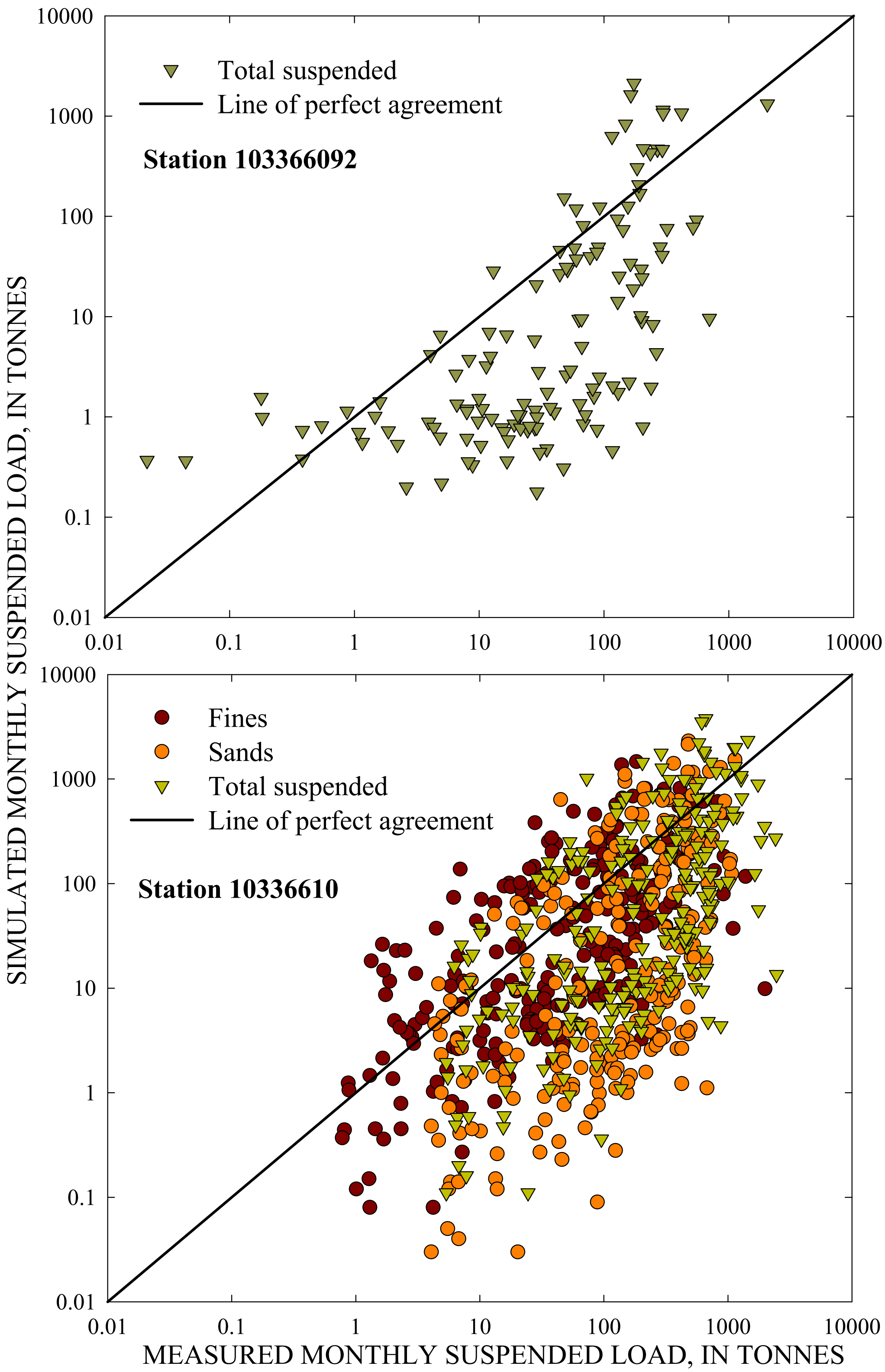

Figure 5-62. Comparison of measured and simulated mean-monthly total suspended sediments for USGS Gages 103366092 (A) and 10336610 (B), for the periods 1991-2001 and 1981-2001, respectively.

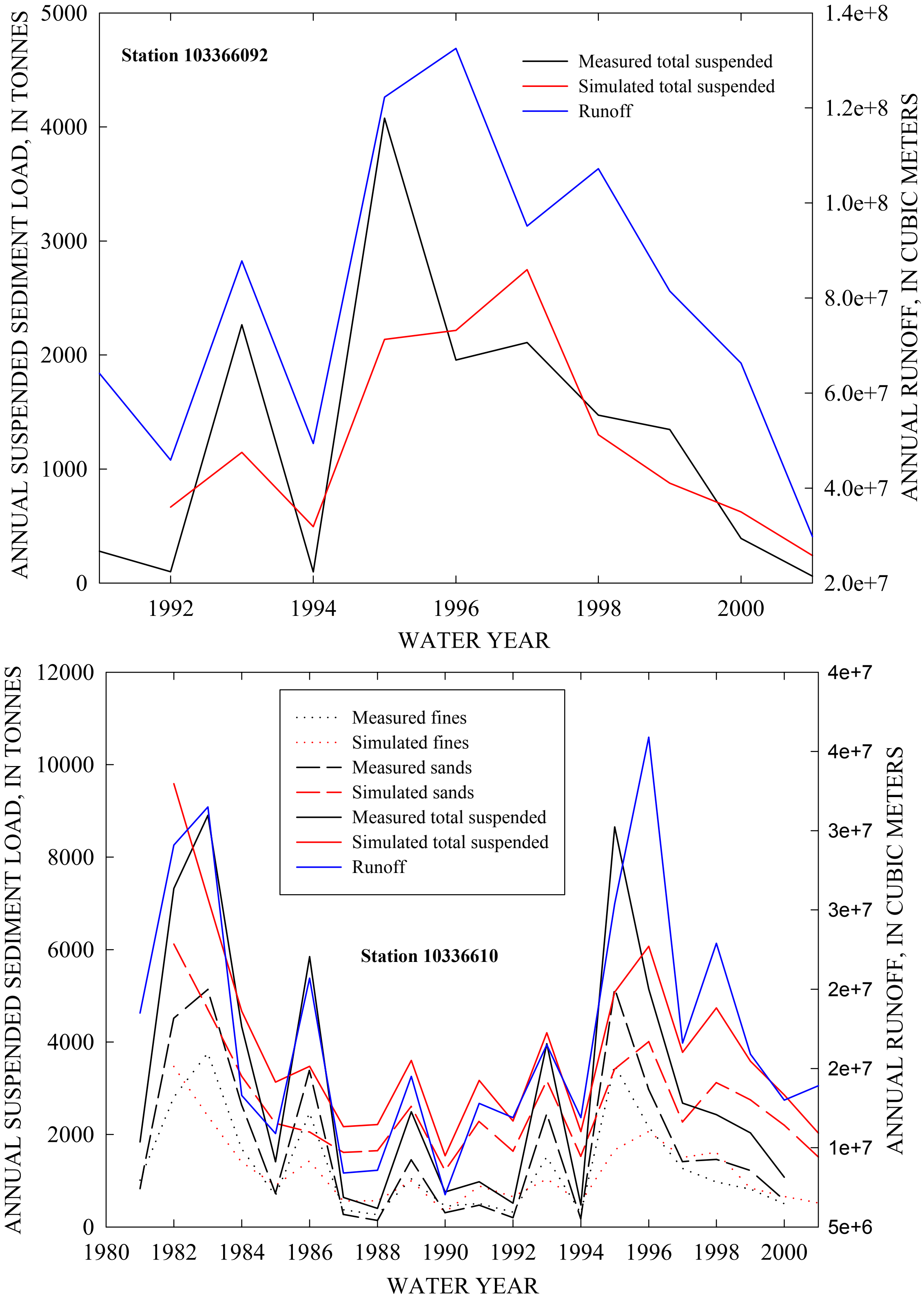

Figure 5-63. Comparison of measured and simulated annual loads at mid-reach gage 103366092 (A) and downstream gage 10336610 (B) for the period of 1991-2001 and 1981-2001, respectively.

Table 5-11. Relative contributions of uplands and streambanks to suspended sediment load during validation period, Upper Truckee River.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	49	51	782
Sands	10	90	2110
Total suspended	21	79	2892

Annually-averaged monthly sediment load of fines, sands, and total suspended sediment are shown in Figure 5-64. It shows that runoff in the fall and winter is relatively large, and that during spring it is relatively low. Consequently, the sediment loads in fall and winter are also high, whereas it is too small in spring. This may partly explain the considerable scatter in Figure 5-62. It appears that simulated snowfall in the fall and winter periods melts too early due to overly warm temperatures at high elevations.

Of the total amount of fines delivered to the channel 49% is eroded from the uplands and 51% from the streambanks (Table 5-11). Streambanks are the principal source of sediments contributing 90% of the sands and 79% of the total suspended sediment over the validation period. About half of the fines emanating from the Upper Truckee River come from streambanks, the rest from uplands. Median, annual loadings of fines at the downstream, index station (10336610; 1010 T/y) compare well simulated values of 782 T/y (Table 5-11).

CONCEPTS 50-Year Simulation

A simulation with a 50-year flow record was performed to determine temporal trends in sediment loads. The channel geometry is the same as in the validation simulation, except the geometry of cross sections 19 through 26 is replaced by that surveyed in 2002. All physical properties are those determined from the validation. The records of tributary and lateral inflow of water and sediments were constructed in the same way as for the validation case. The runoff in years 22 through 42 is the same as in years 1 through 21 of the 50-year flow record, except the large storm event on January 2 of year 17 is not repeated in year 38. The runoff in years 43 through 50 is the same as in years 1 through 8.

Changes in channel top width and bed elevation over the 50-year simulation period are shown in Figure 5-65. Channel top-width changes significantly at cross sections 24 (34 m), 22 (12 m), and 19 (8 m) and represent the principle form of channel change over the next 50 years. The average change in top width is 2.7 m for the 23.4 km reach. Changes in thalweg elevation range from 0.2 m of erosion at cross section 20 to 1.1 m of deposition at cross section 24, thus channel depths will generally decrease over the 50-year simulation period.

Although runoff volumes are repeated for years 1-21 and 22-42, and 43-50, suspended-sediment loads decrease over the period, not withstanding another simulated January 1997 runoff event. Figure 5-66 shows the simulated annual runoff, and annual loads of fines, sands, and total suspended sediments at the outlet of the Upper Truckee River. Channel adjustments in the first 23 years comprise 58 percent of the total change in the 50-year simulation.

Streambanks are the principal source of sediments, contributing 80% of the sands and 66% of the total suspended sediment. Table 5-12 lists the sources of fines and sands delivered to the channel outlet and their relative contributions. Of the total amount of fines delivered to the channel over the 50-year simulation period, 63% is eroded from the uplands and 37% from the streambanks.

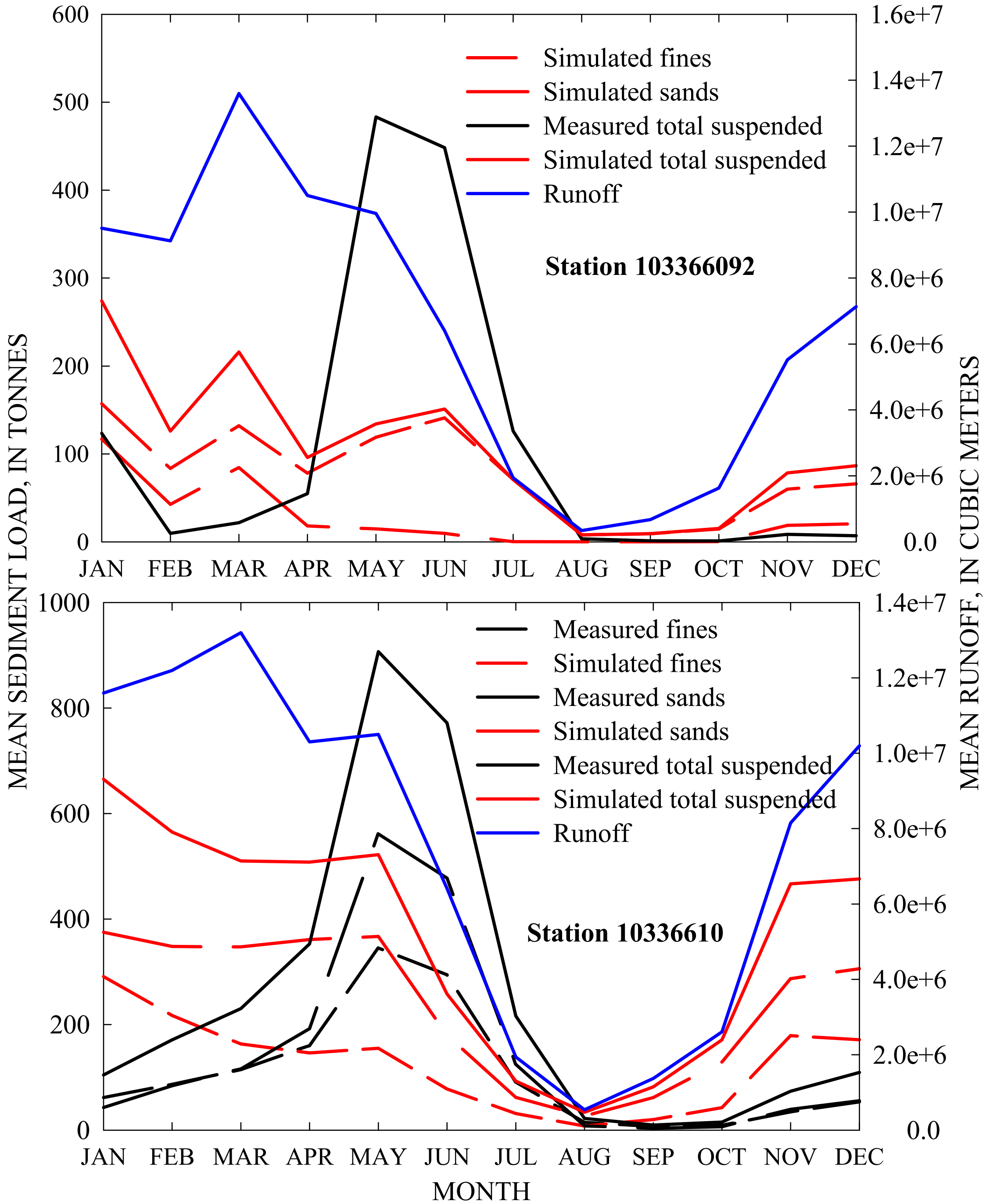

Figure 5-64. Comparison of measured and simulated annually-averaged monthly sediment loads and runoff for stations 103366092 (A) and 10336610 (B).

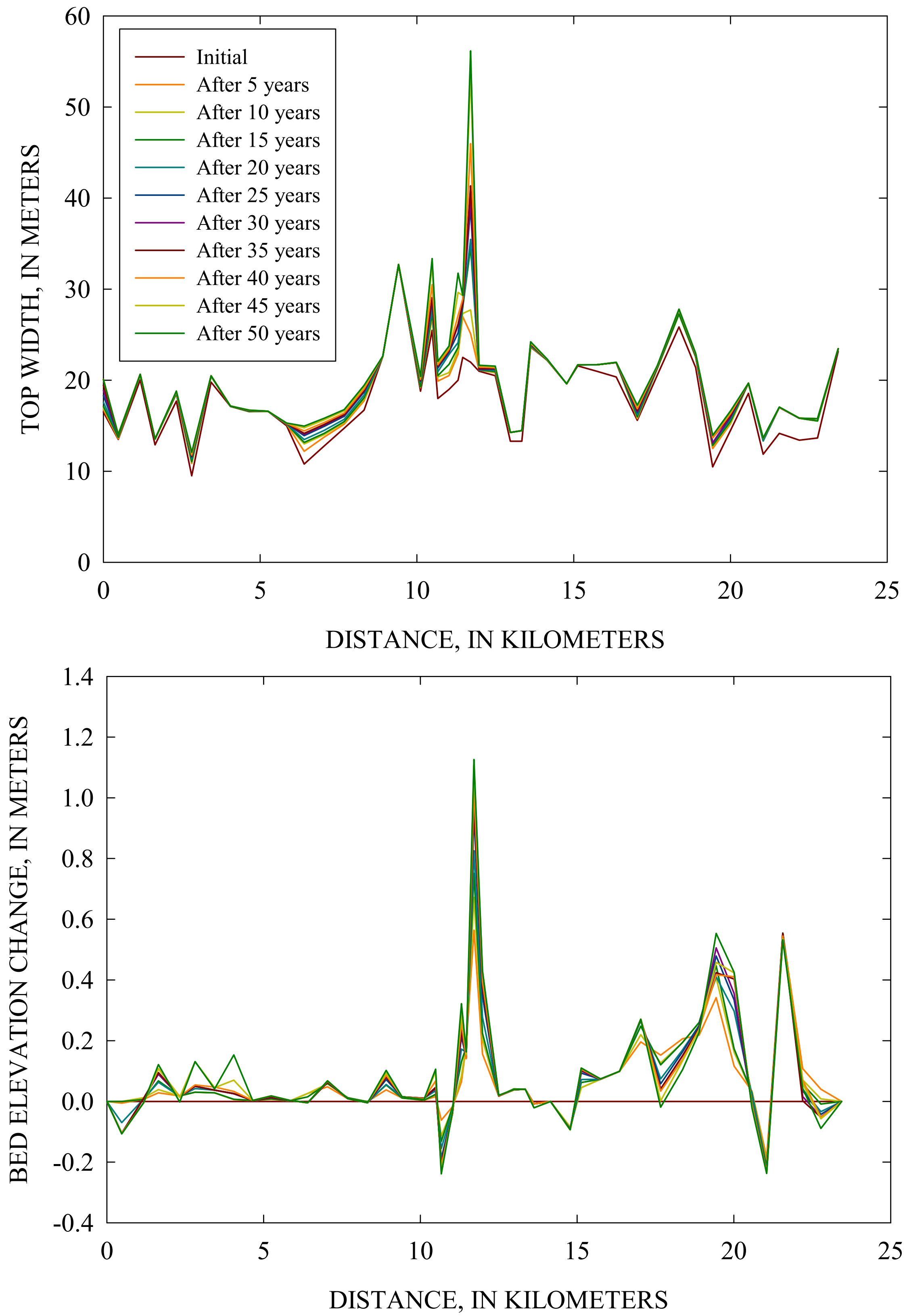

Figure 5-65. Simulated changes in bank top-width and bed elevation of the Upper Truckee River over a 50-year period.

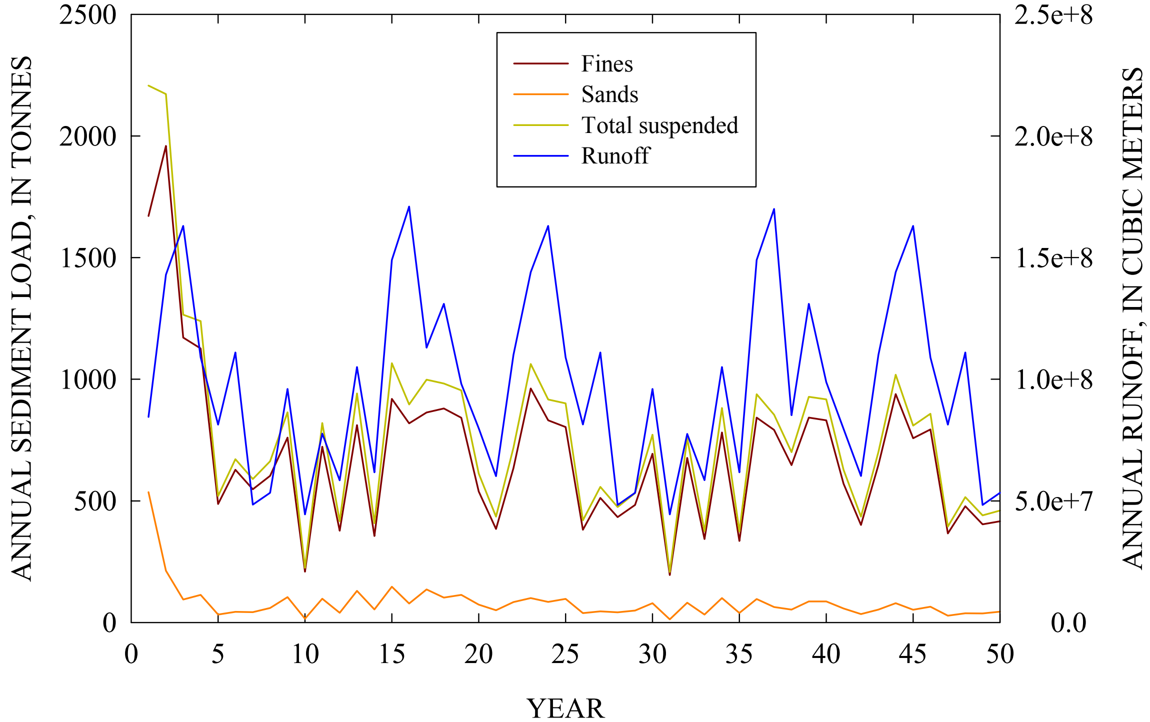

Figure 5-66. Simulated annual runoff and loads of fines, sands, and total suspended sediments delivered to the lake for the 50-year period.

Table 5-12. Relative contributions of uplands and streambanks to suspended sediment load over the 50-year simulation period.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	63	37	803
Sands	20	80	1714
Total suspended	34	66	2517

5.4.3 Ward Creek

AnnAGNPS

Three gaging stations (10336676 at the lower end, 10336675 in the middle and 10336674 at the upper end) are used to validate simulations of AnnAGNPS within the Ward Creek watershed. There were several techniques used to evaluate the performance of AnnAGNPS in the Ward Creek watershed by comparing annual and monthly runoff and sediment, as well as an evaluation of the sources of the runoff and sediment within the watershed.

<u>Annual Runoff</u>. Simulated annual runoff was determined from 1980 to 2001 at stations 10336674 10336675, while measured runoff was available from 1992 to 2000 (Figures 5-67 and

5-68). Simulated annual runoff was determined from 1980 to 2001 at the downstream, index station 10336676, while measured runoff was available from 1980 to 2000 (Figure 5-69). As with the Upper Truckee River watershed simulations, simulated annual runoff compares well with measured values.

Monthly Runoff. The simulated monthly runoff was compared with the measured for all months from 1992-2000 at the USGS gaging station #10336674 (Figure 5-70) and at USGS gaging station #10336675 (Figure 5-71). The simulated monthly runoff was compared with the measured for all months from 1980-2000 at the USGS gaging station #10336676 (Figure 5-72). Although the graphs show reasonable agreement between absolute values, monthly values are still somewhat overestimated during the winter months probably due to problems with temperature gradients.

Annual Fine-Sediment Loads. Simulated annual fine-sediment loads were compared to calculated annual fine-sediment transport at the three stations in the watershed (Figures 5-73 to 5-75). Results show that at the upstream-most station (10336674) fine-sediment contributions from upland sources was higher than the lower gages. This is in general agreement with observations of Stubblefield (2002) and the load calculations for these gages in section 3.4. As with the simulations of the other watersheds, the proportion of sediment from upland areas making up the total suspended-sediment load passing downstream stations decreases with increasing distance from the headwaters as a probable result of more channel erosion occurring downstream.

Sources. TA significant amount of runoff occurs in the upper end of the watershed where the land cover is rock outcrop (Figure 5-76). Total erosion and fine-sediment yield that reaches the edge of each AnnAGNPS cell shows considerable variability throughout the watershed, but is generally higher in the upper end of the watershed owing to steeper slopes and unconsolidated geologic formations (Figure 5-78). These have been noted by Stubblefield (2002) and others, and are documented in this report with the short period of loadings data from station 10336670.

Recurrence Interval for the Annual Maximum Instantaneous Peak Discharge. Tables 5-13 through 5-15 list the observed annual peak discharges at stations 10336674, 10336675, and 10336676, respectively, with the simulated, annual peak discharges computed by AnnAGNPS routed downstream by CONCEPTS. Simulated annual peak discharges are about 50 percent larger than those observed. The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 6.6, 13.7, 20.1, and 27.6 m^3/s, respectively.

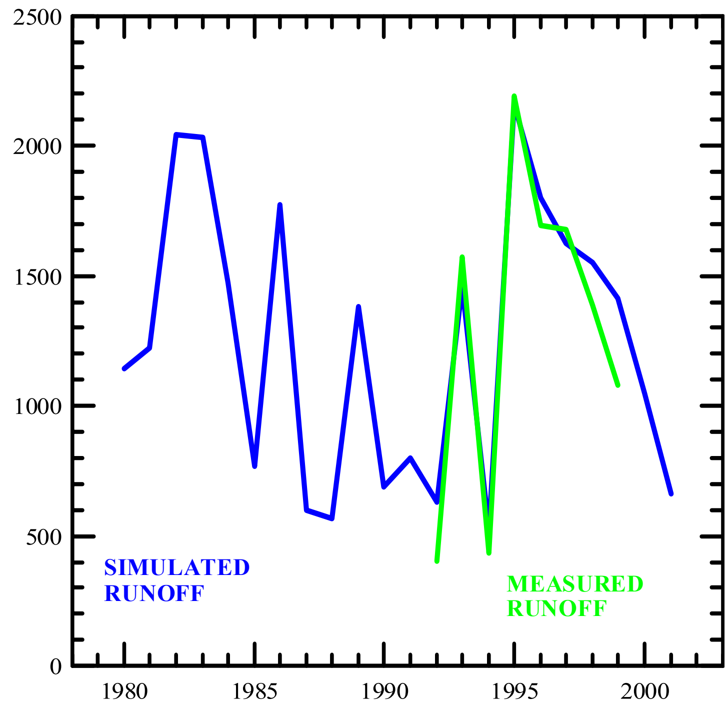

Figure 5-67. AnnAGNPS simulated and measured annual runoff at station 10336674, Ward Creek watershed.

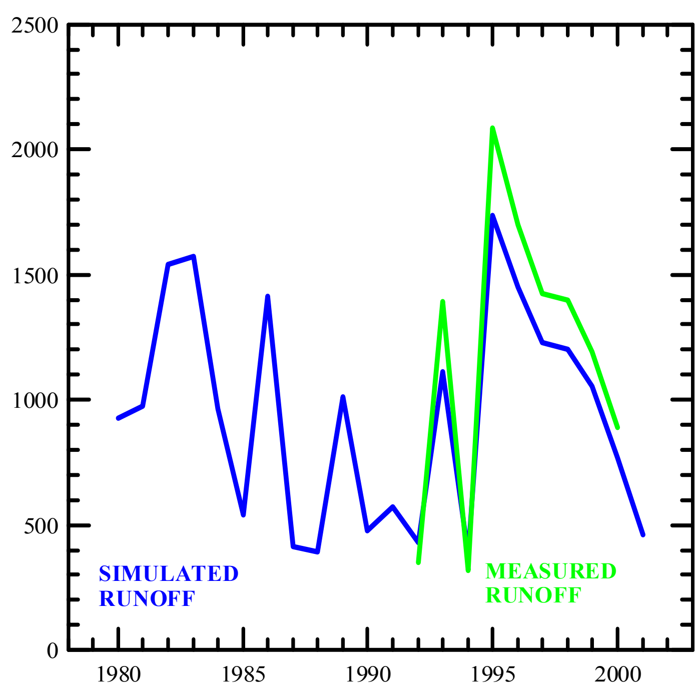

Figure 5-68. AnnAGNPS simulated and measured annual runoff at station 10336675, Ward Creek watershed.

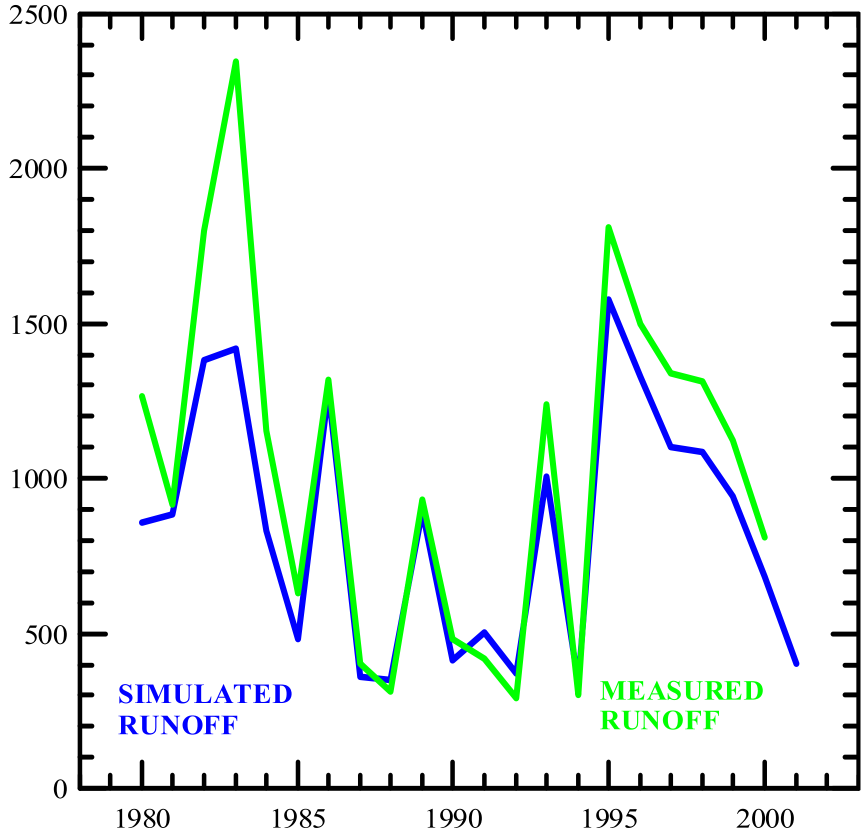

Figure 5-69. AnnAGNPS simulated and measured annual runoff at station 10336676, Ward Creek watershed.

At USGS gaging station 10336675 the simulated annual peak discharges agree better for the less frequent large runoff events, but are still much too big for the more frequent moderate runoff events. The simulated peak discharge (66.4 m^3/s) for the January 1-2, 1997 runoff event agrees very well with that observed (67.1 m^3/s). The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 9.3, 21.9, 35.8, and 55.1 m^3/s, respectively. The corresponding simulated peak discharges are: 10.5, 23.6, 38.7, and 60.9 m^3/s, respectively.

At USGS gaging station 10336676 the agreement between observed and simulated annual peak discharges worsens for annual peak discharges falling within the 1- to 2-year recurrence interval. The observed peak discharges reduce between stations 10336675 and 10336676, whereas the simulated peak discharges increase very slightly. The 2-year, 5-year, 10-year, and 20-year peak discharges calculated from the observed annual peaks are 7.9, 19.7, 33.1, and 51.8 m^3/s, respectively. The corresponding simulated peak discharges are: 11.9, 25.1, 39.2, and 58.6 m^3/s, respectively.

Table 5-13. Comparison of measured and simulated annual peak discharge at USGS gaging station 10336674. Values are in cubic meters per second.

Water year	Observed	Water year	Observed
1992	1.44	1997	34.6
1993	8.95	1998	6.29
1994	2.27	1999	7.48
1995	6.65	2000	7.42
1996	12.29	2001	5.66

Table 5-14. Comparison of measured and simulated annual peak discharge at USGS gaging station 10336675. Values are in cubic meters per second.

Water year	Observed	CONCEPTS	Water year	Observed	CONCEPTS
1992	2.86	4.00	1997	67.1	66.4
1993	11.8	8.06	1998	9.54	22.2
1994	2.46	4.84	1999	11.0	8.93
1995	10.5	18.4	2000	12.4	7.61
1996	24.5	29.0	2001	4.96	5.08

Table 5-15. Comparison of measured and simulated annual peak discharge at USGS gaging station 10336676. Values are in cubic meters per second.

Water year	Observed	CONCEPTS	Water year	Observed	CONCEPTS
1981	4.19	9.44	1992	3.11	4.08
1982	51.0	44.3	1993	13.1	8.81
1983	18.0	15.91	1994	2.58	5.69
1984	9.94	29.2	1995	14.5	20.9
1985	4.64	9.40	1996	28.9	31.1
1986	24.4	50.1	1997	71.6	72.6
1987	3.20	6.87	1998	10.5	26.3
1988	1.36	5.70	1999	11.2	9.44
1989	6.03	13.3	2000	12.2	7.59
1990	2.46	5.75	2001	5.72	5.39
1991	3.37	8.70			

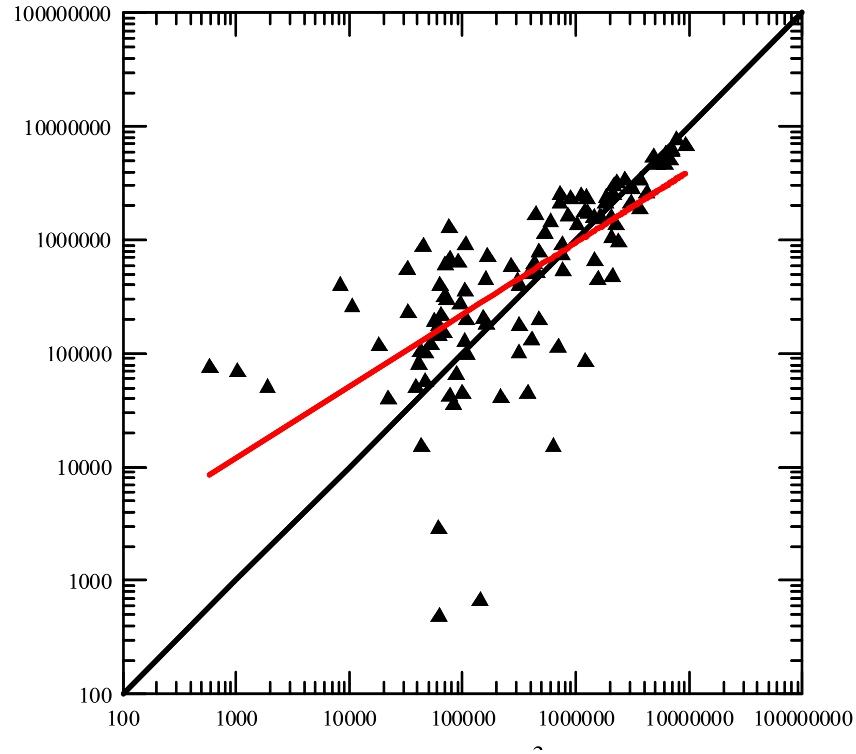

Figure 5-70. AnnAGNPS simulated versus measured monthly runoff during 1991-2000 at the upstream station 10336674, Ward Creek watershed.

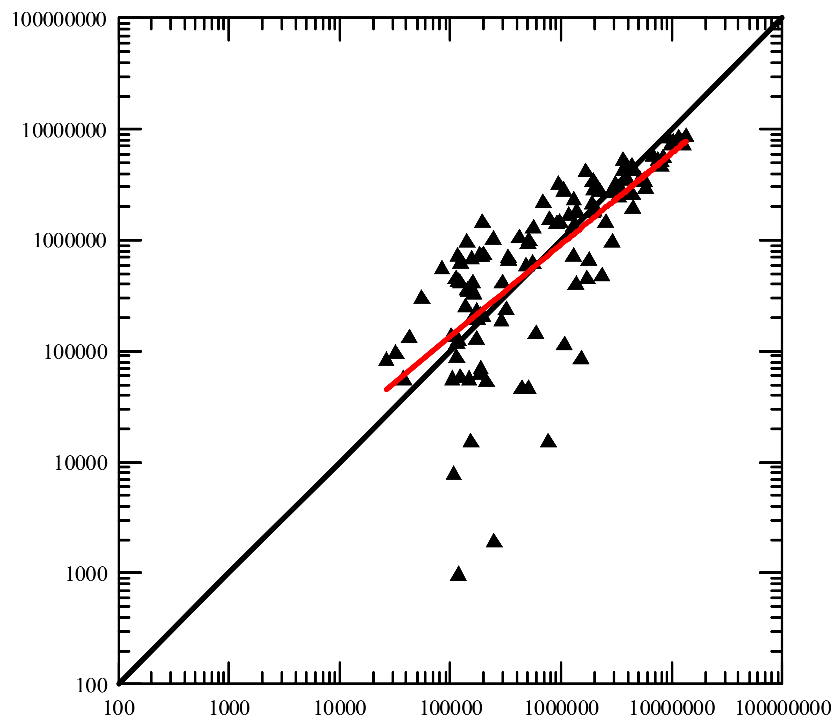

Figure 5-71. AnnAGNPS simulated versus measured monthly runoff during 1991-2000 at the middle station 10336675, Ward Creek watershed.

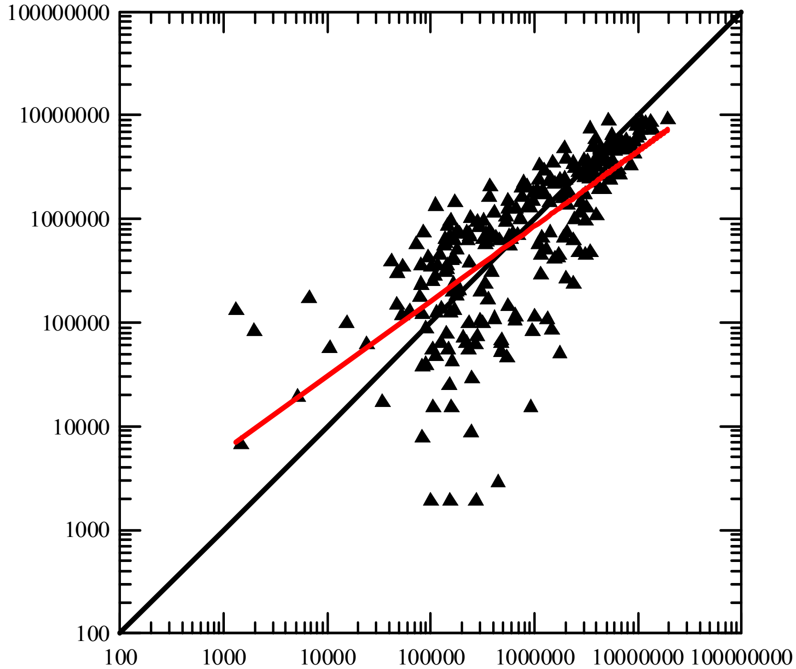

Figure 5-72. AnnAGNPS simulated versus measured monthly runoff during 1981-2000 at the downstream station 10336676, Ward Creek watershed.

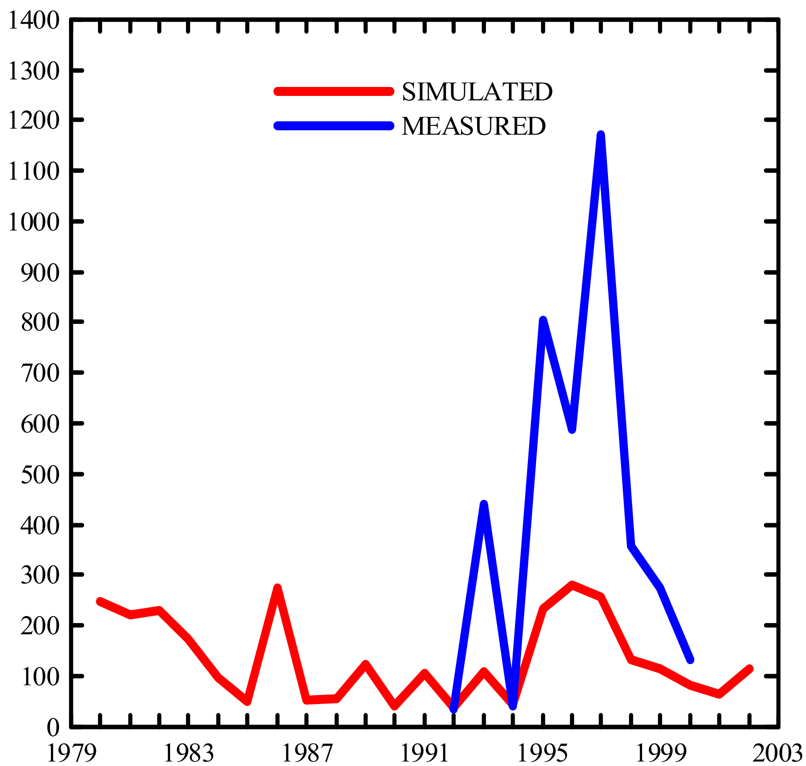

Figure 5-73. AnnAGNPS simulated and measured yearly sediment at the upstream station 10336674, Ward Creek watershed.

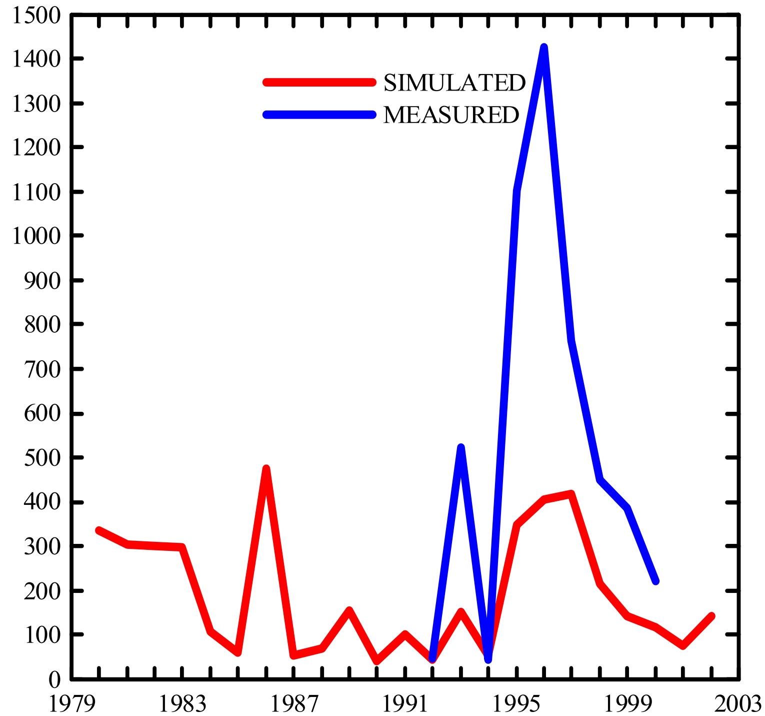

Figure 5-74. AnnAGNPS simulated and measured yearly sediment at the USGS gaging station 10336675, Ward Creek watershed.

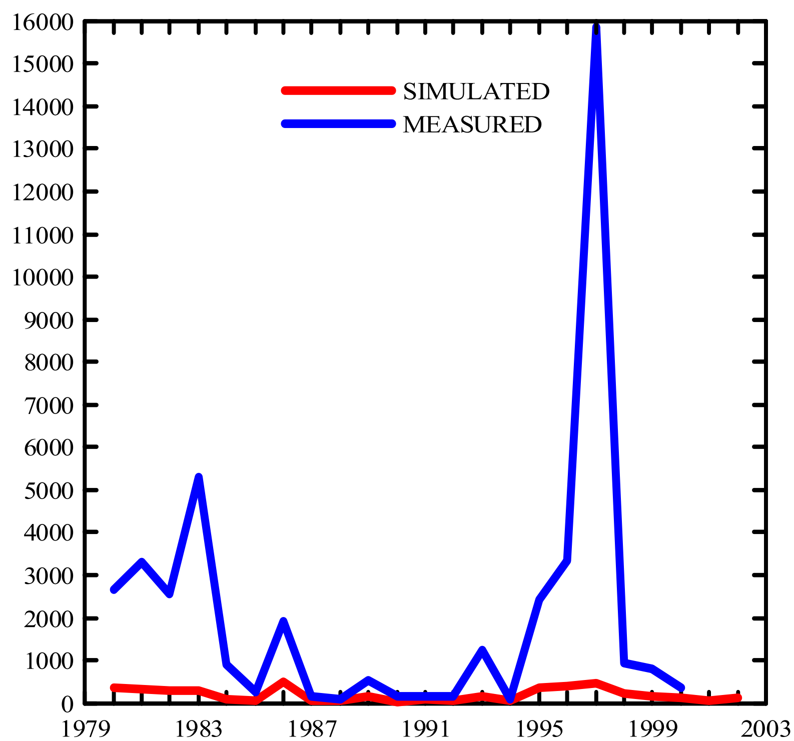

Figure 5-75. AnnAGNPS simulated and measured yearly sediment at the downstream station 10336676, Ward Creek watershed.

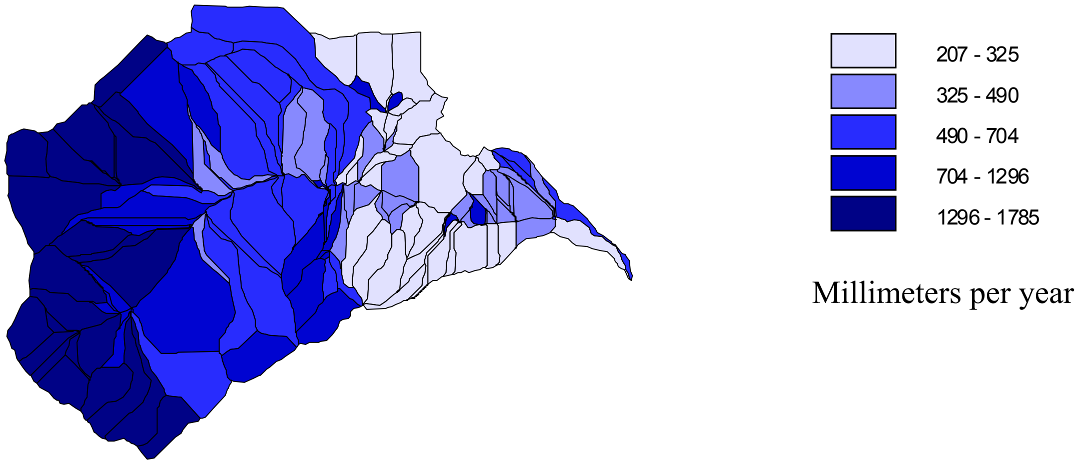

Figure 5-76. Average annual runoff simulated from AnnAGNPS for each cell on Ward Creek watershed.

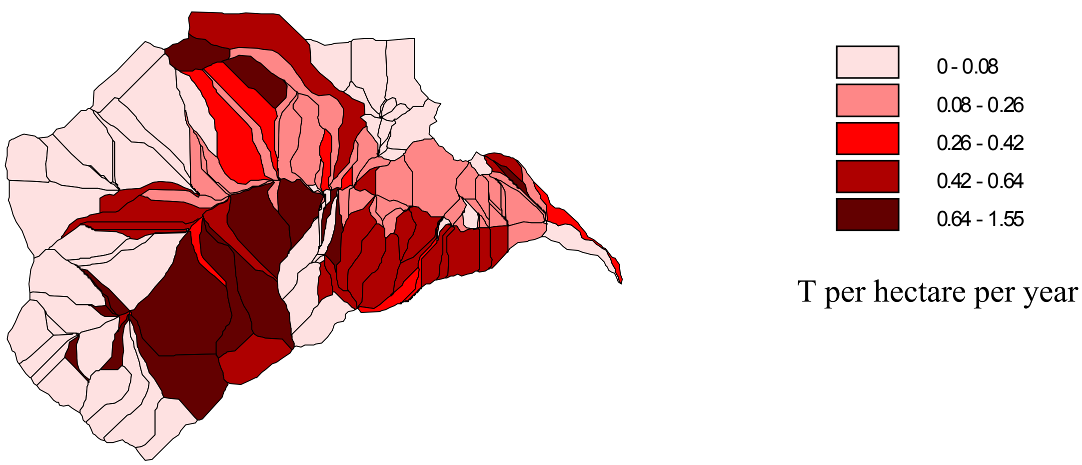

Figure 5-77. Average annual erosion simulated from AnnAGNPS for each cell on Ward Creek watershed.

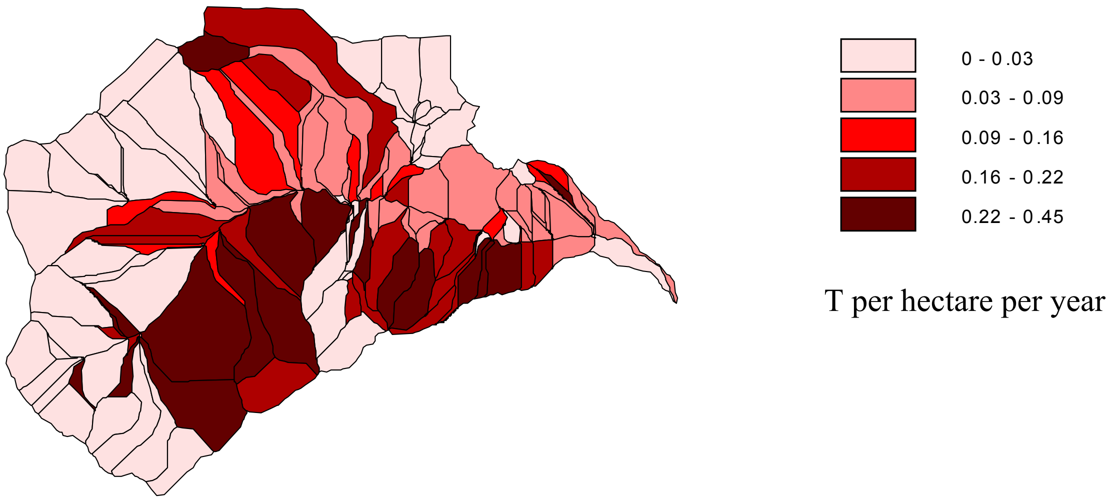

Figure 5-78. Average annual sediment yield simulated from AnnAGNPS for each cell on Ward Creek watershed.

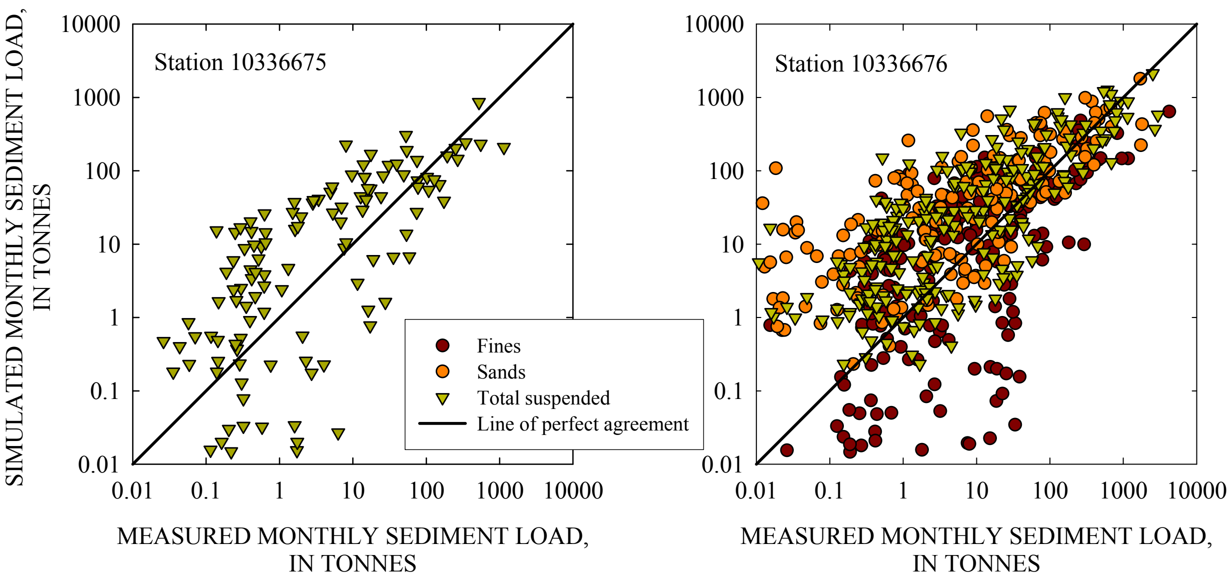

Figure 5-79. Comparison of measured and simulated mean-monthly loads of fines (clay and silts), sands, and total suspended sediment at Ward Creek.

CONCEPTS Validation

Estimated sediment loads at stations 10336675 and 10336676 (see section 3.4) were used to validate CONCEPTS for the period from January 1981 through September 2001. Figures 5-79 through 5-81 show the results of the validation. Simulated annual peak discharges are listed in Tables 5-14 and 5.15 and discussed above.

<u>Sediment Load</u>. Figure 5-79 compares measured and simulated mean-monthly loads of fines (clay- and silt-sized particles), sands, and total suspended sediments. The points plot

around the line of perfect agreement. The observed scatter is to be expected in light of the variability between measured and simulated mean-monthly runoff. At station 10336675 the r^2 value for total suspended sediments is 0.41. At station 10336676 the r^2 values for fines, sands, and total suspended sediments are 0.41, 0.52, and 0.56 respectively.

Generally, annual loads appear to be correlated with annual runoff (Figure 5-80). Years with low runoff correspond to years with low annual sediment loads. Increased measured loads in 1997 are caused by channel erosion, particularly bank widening during the January 1997 runoff event. Between 1992 and 2001 the measured average-annual total suspended sediment load was 504 T at gaging station 10336675. The corresponding simulated average annual load of total suspended sediment is 530 T. The simulated annual loads in 1995 and 1996 are smaller than those measured. However, simulated loads were already underestimated by AnnAGNPS at the upstream boundary of the model (station 10336674, see AnnAGNPS simulation). The simulated annual load in 1997 is larger than that measured and may be a function of either (1) the accuracy of the calculated load at the gage because it is much smaller than the annual load at the upstream station (10336674), and/or (2) as observed by Stubblefield (2002) and discussed in section 4.6.3, significant streambed deposition occurs between these two stations.

Between 1981 and 2001 the measured, average-annual fine, coarse, and total suspended sediment loads were 713, 1217, and 1930 T, respectively at the downstream, index station 10336676. The corresponding simulated average annual loads are 409, 1009, and 1418 T, respectively. The discrepancy between measured and simulated suspended load at station 10336676 is due to a large calculated sediment load on January 2, 1997. Omitting water year 1997 from the measured average annual load yields 523, 700, and 1223 T for fine, sand, and total suspended sediment load, respectively. The corresponding simulated average annual loads are 371, 923, and 1293 T, respectively. The simulated average annual load of fines (clays and silts) is underestimated whereas that of sands is overestimated.

Most sediment is transported during the snowmelt period from April through June (Figure 5-81). The simulated sediment loads during this period are somewhat under-predicted and is related to too much runoff in the fall and winter, and hence too little during the snow melt period.

Streambanks are the principal source of suspended sediment, contributing 86% of the sands and 66% of the total suspended sediment. Table 5-16 lists the sources of fines and sands delivered to the channel outlet and their relative contributions. Of the total amount of fines delivered to the channel 79% is eroded from the uplands and 21% from the streambanks.

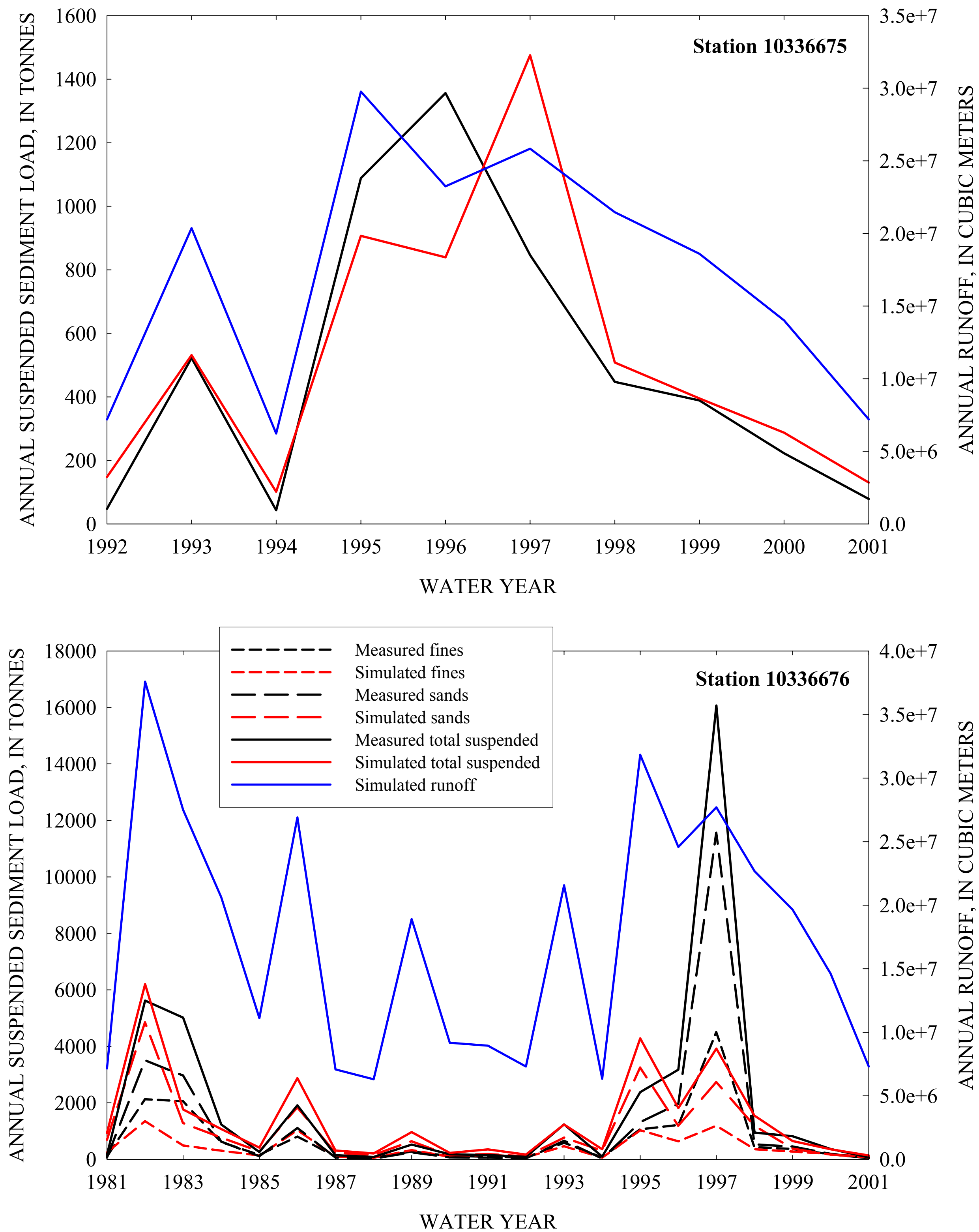

Figure 5-80. Comparison of measured and simulated annual loads at Ward Creek.

Table 5-16. Relative contributions of uplands and streambanks to suspended sediment load at the outlet of Ward Creek for the validation simulation.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	79	21	210
Sands	14	86	485
Total suspended	34	66	695

50-Year Simulation

A simulation with a 50-year flow record was performed to determine trends in sediment loads. The channel geometry is based on the 2002 cross section survey. All physical properties are those determined from the validation. The records of tributary and lateral inflow of water and sediments were constructed in the same way as the validation case. The runoff in years 24 through 46 is the same as in years 1 through 23 of the 50-year flow record, except the large storm event on January 2 of year 18 is not repeated in year 41 (see AnnAGNPS section). The runoff in years 47 through 50 is the same as in years 1 through 4.

Figure 5-82 shows the changes in channel top width and bed elevation over the 50-year simulation period. Top width changes only significantly at cross sections 2 and 14. Changes in thalweg elevation range from 0.05 m of erosion at cross section 9 to 0.12 m of deposition at cross section 14.

Figure 5-83 shows the simulated annual runoff, and annual loads of fines, sands, and total suspended sediments at the outlet of Ward Creek. The annual loads in years 1 through 23 are larger than those in years 24 through 50 though annual runoff is the same. Channel adjustments in the first 23 years are larger than those in years 24 through 50.

Table 5-17 lists the sources of fines and sands delivered to the channel outlet and their relative contributions. Of the total amount of fines delivered to the channel 84% is eroded from the uplands and 16% from the streambanks. Streambanks are the principal source of sediments, they contributed 86% of the sands and 61% of the total suspended sediment. Upland sources, however, are the main source of fine-grained materials from the watershed (Table 5-17).

Table 5-17. Relative contributions of uplands and streambanks to suspended sediment load at the outlet of Ward Creek for the 50-year simulation.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	84	16	200
Sands	14	86	353
Total suspended	39	61	553

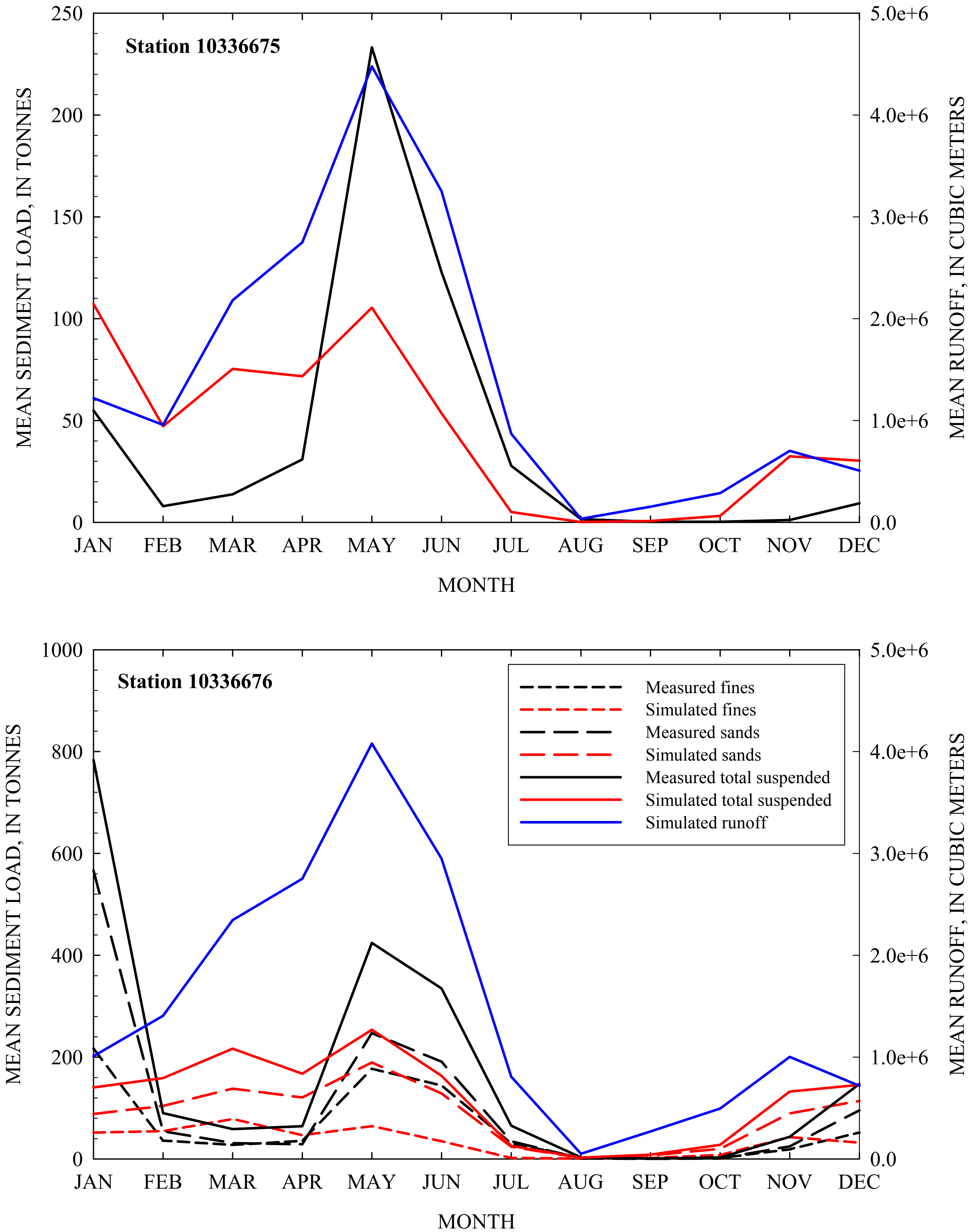

Figure 5-81. Comparison of measured and simulated annually-averaged monthly sediment loads and runoff at Ward Creek.

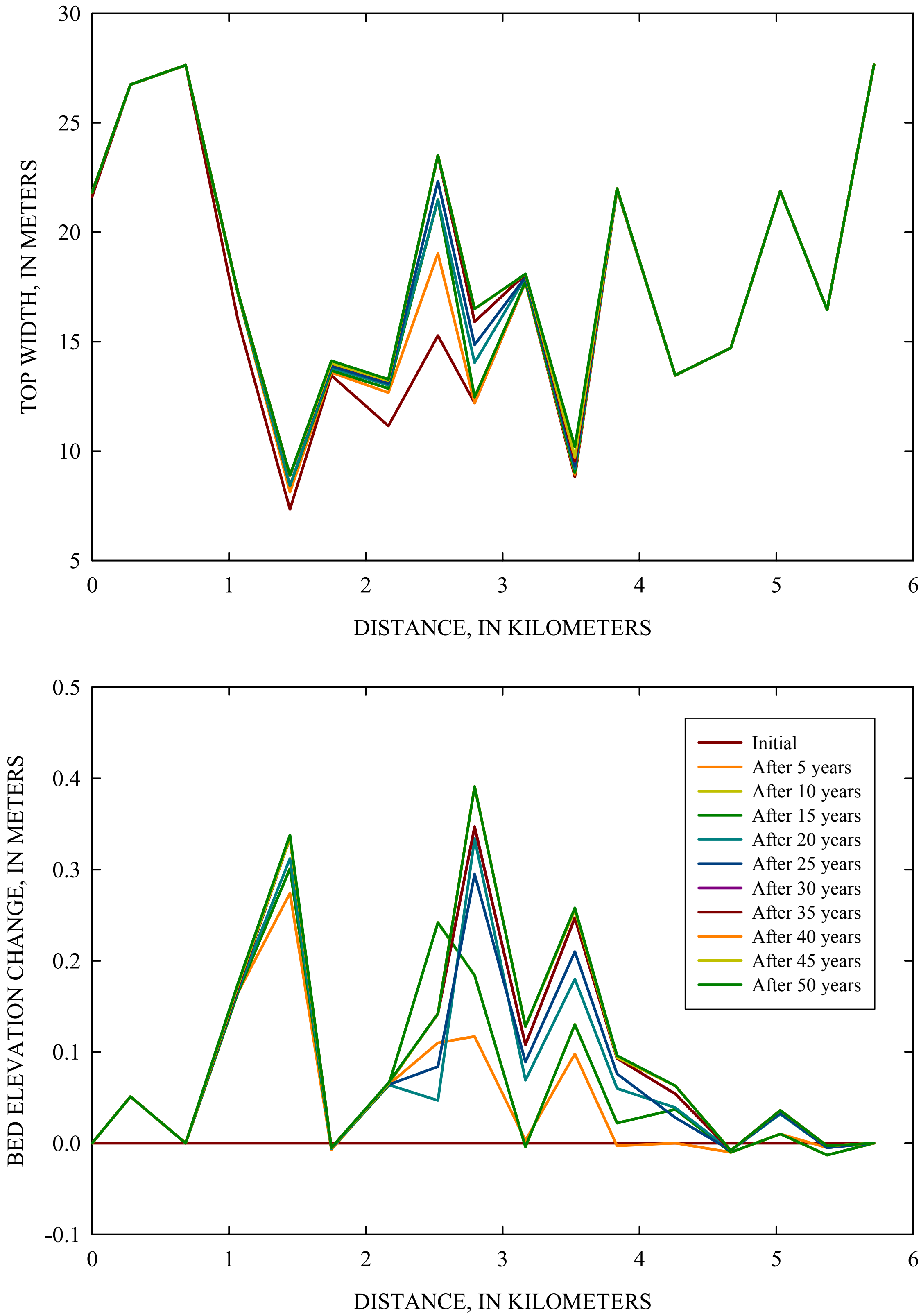

Figure 5-82. Simulated changes in bank top-width and bed elevation of Ward Creek over a 50-year period.

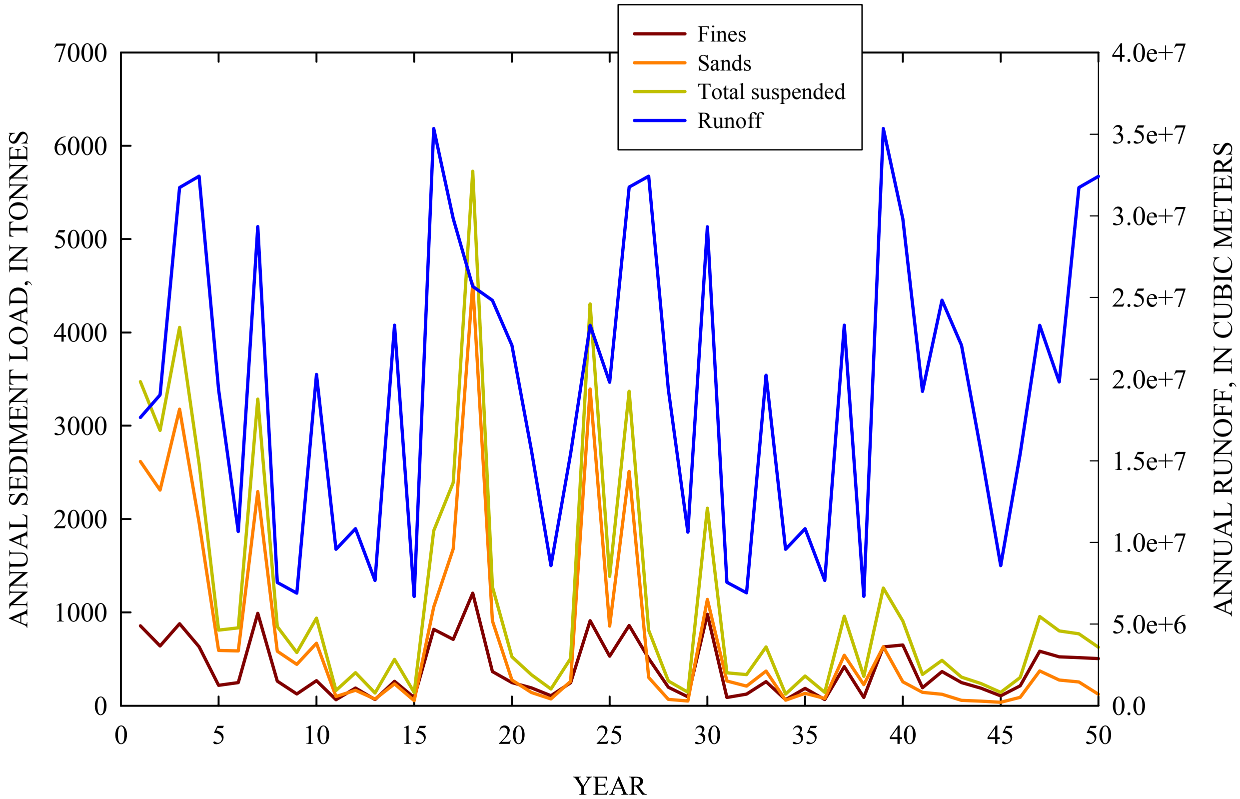

Figure 5-83. Simulated annual runoff and loads of fines, sands, and total suspended sediments at the outlet of Ward Creek for the 50-year simulation.

5.5 <u>Summary</u>

The USDA watershed and channel evolution models AnnAGNPS and CONCEPTS were used to simulate the sediment loadings to Lake Tahoe from General and Ward Creeks, and the Upper Truckee River over a 50-year period. The models were validated using: (1) discharges and sediment loads measured at USGS gaging stations in the three watersheds, and (2) measured changes in cross-sectional geometry at selected reaches of General Creek and the Upper Truckee River.

Climate information, particularly precipitation and temperature, is the most important factor to accurately simulate runoff. Unfortunately, the current climate data available for the Lake Tahoe Basin is inadequate for detailed numerical modeling in some watersheds. A 50-year numerical simulation of climate produced by a concurrent study was not available for this research. are very poor in most locations. For instance, there is no climate station located within the General Creek watershed. Precipitation and temperature at the Tahoe City climate station were used to represent the weather at General Creek watershed. For the Upper Truckee River watershed, accurate climate data are only available for its western-most region near Echo Lake. Climate data from Hagan’s Meadow climate station (Trout Creek watershed) were used to complement the available data within the Upper Truckee River watershed. Both these stations are at high elevations (2440 m). Historic climate data at lower elevations in the Upper Truckee River watershed is limited to a few months that describe precipitation at the airport. The available climate data for Ward Creek watershed is better than for the other two watersheds.

Comparisons between simulated and measured data at the USGS gaging locations were made based on monthly and yearly totals to avoid the uncertainties involved with comparisons of individual dates. Also, AnnAGNPS has been designed for applications of long-term simulations; hence, individual event-based comparisons may distort how well the model actually performs.

The validation period for General Creek is 1981 to 2001. Cross -section surveys were carried out in 1983 and 2002. Simulated runoff volumes are lower than measured for General Creek (Figures 5-35 through 5-37), whereas peak discharges are high (Table 5-5). The applied precipitation used by the model was most likely too low at the upper end of the watershed. Simulated morphological changes and sediment loads agree very well with those estimated (Figures 5-43 through 5-46).

Average, annual suspended load at the downstream, index station (10336645) is 238 T, whereas AnnAGNPS and CONCEPTS simulated an average annual suspended load of 272 T. The difference is caused by an overestimation of the sand transport, which may be due to the model assumption that all sand-sized particles (diameter between 0.063 and 2 mm) are being transported in suspension. Still, these results are with 14%, an exceptional result given all of the inherent uncertainties.

Based on the simulation results, 72% of the fine suspended load (clay and silt) at the mouth of General Creek is contributed from the uplands and 28% from the channel. The coarse suspended load (sands) is mainly generated in the channel (60%). The simulated annual volumetric change in channel geometry per unit of channel length is 10.6 m^3/yr/km. This agrees quite well with that calculated from the surveyed change in cross section geometry (14.6 m^3/y/km). The simulated percentage of fine sediments (clay and silt) eroded from the channel is 8.5%, whereas the survey-based percentage of eroded fine sediments is 10.3%.

The 50-year simulation of General Creek predicts that 195 T/y of sediments are discharged into Lake Tahoe. Of this total, 51 T/y are clays and silts. The majority of sediments (60%) are generated in the first 25 years when channel-erosion processes are more active.

The validation period for the Upper Truckee River is 1981 to 2001. Cross section surveys for a highly active reach upstream of the airport were carried out between 1992 and 2002. Simulated runoff volumes (Figures 5-49 through 5-51) and annual peak discharges (Tables 5-8 through 5-10) along the Upper Truckee River are high compared to measured. The annual loads of suspended sediments are predicted fairly well at the mid-reach station (103366092) near Myers (Figure 5-63A). The simulated average annual load of suspended sediments is 1287 T compared with 1250 T measured. Simulated sand transport was higher than measured (2814 T versus 1700 T) at the downstream station (10336610) in South Lake Tahoe (Figure 5-63B), whereas the simulated average, annual fine-suspended load (1486 T) compares well with that measured (1258 T). Further, there is too much sediment transport during the fall and winter period, and too little during the spring (snowmelt) season (Figure 5-64).

Streambanks are the major source of sediments based on simulation results at the mouth of the Upper Truckee River: 49% of the fine suspended load (clay and silt), 90% of the coarse suspended load (sands), and 79% of the total suspended load. Simulated changes in bank-widening rates were reasonably good along the surveyed reach (between river km 11.7 and 13.7) (Figure 5-61). Difficulties were encountered in simulating toe erosion and incision in the reach on outside bends because CONCEPTS is a one-dimensional model.

The 50-year simulation of the Upper Truckee River predicts that annually 770 T/y of sediment will be discharged to Lake Tahoe. Of this total, 690 T/y are clays and silts. The majority of sediments (60%) are generated in the first 25 years when channel erosion, particularly bank widening is most active. Almost two-thirds of the total suspended-sediment is simulated to come from streambank erosion. Of the total mass of fine-grained sediments delivered to the lake over the 50-year simulation period, 37% are from streambanks, with the balance from upland sources.

The validation period for Ward Creek is 1981 to 2001. Simulated runoff volumes are lower than measured (Figures 5-68 and 5-69), but annual peak discharges are predicted fairly well (Tables 5-13 through 5-15). The simulated average annual suspended sediment load agrees quite well with those calculated from measured data (Figure 5-80): (1) 504 T (measured) versus 530 T (simulated) at USGS gaging station 10336675, and (2) 1223 T (measured) versus 1293 T (simulated) at USGS gaging station 10336676. The suspended load in water year 1997 has been omitted from the latter values, because the measured value for that year seems to be extremely large and may not be realistic. Based on the simulation results, 79% of the fine suspended load (clay and silt) at the mouth of Ward Creek is contributed from the uplands and 21% from the channel. The coarse suspended load (sands) is mainly generated in the channel (86%).

The 50-year simulation of Ward Creek predicts that annually 1150 T of sediments are discharged into Lake Tahoe. Of this total, 400 T are clays and silts, delivered primarily from upland sources (84%). The majority of sediments (70%) are generated in the first 25 years when channel erosion is more active.

The differences between simulated and measured runoff from the three watersheds can be significantly reduced with improved climate data, mainly precipitation and temperature. Precipitation and temperature are highly dependent on weather patterns and elevation (see Figures 5-21 and 5-22), and therefore, vary widely across each watershed. Precipitation will affect runoff volume, whereas temperature will determine whether precipitation occurs as rain or snow, and the timing of snowmelt. Hence, both simulated runoff volume and timing of runoff could be improved with better climate data, reducing the differences between measured and simulated runoff. Figure 5-31 shows that snowmelt can be represented by a triangular hydrograph superimposed on a certain base flow. However, AnnAGNPS and CONCEPTS do not simulate a base flow. Consequently, the constructed triangular hydrographs may have unrealistically high peaks. Determining the base flow during snowmelt may therefore lead to improved prediction of annual peak discharges.